

## **UNDP INITIATIVE FOR SUSTAINABLE ENERGY**

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Energy and Atmosphere Programme  
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Bureau for Policy and Programme Support  
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Fax No. (212) 906-5148  
Tel No. (212) 906-5030

*This document was prepared by the Energy and Atmosphere Programme (EAP) in the Sustainable Energy and Environment Division, BPPS at UNDP in cooperation with other UNDP units and individuals in, and outside of, UNDP. The EAP unit consists of Thomas B. Johansson, Suresh Hurry, Susan McDade, Ad Dankers, Lory Dolar, and Vivette Riley.*

*This document has emerged from a process, beginning with a memorandum by Amulya Reddy, and involving written and verbal contributions from many experts, including M.C. Actouka, Deepak Bayracharya, Michael Bergey, Gustavo Best, Deborah Bleviss, Birgit Bodlund, Susan Burns, Angela Cropper, Ad Dankers, Phil Dobie, Lory Dolar, Martha Duenas, Francois Ekoko, Imad Fakhoury, Jose Goldemberg, Luis Gomez-Echeverri, Michael Gucovsky, Peter Hazelwood, Suresh Hurry, Richard Hosier, Henry Jackelen, Thomas B. Johansson, Karen Jorgensen, Hisham Khatib, Sherry Login, Roberto Lenton, Rob Lichtman, Jim MacNeill, Eric Martinot, Susan McDade, Charles McNeill, Sarah Murison, Sara Nilsson, Sofia Nässström, Maxine Olsen, Frank Pinto, Rajendra K. Pachauri, Rajeev Pillay, Thord Palmlund, Jonas Rabinovitch, Amulya Reddy, Nick Remple, Ralph Schmidt, Susanne Schmidt, Willi Scholl, Firouz Sobaru, James Gustave Speth, Maurice Strong, Dan Temu, Ricardo Tichauer, Sally Timpson, Evan Vallianatos, John Vos, Anders Wijkman, and Robert H. Williams. In addition, it draws heavily on the experience of the International Energy Initiative, India, and the approach outlined in two books: *Energy for a Sustainable World*, by Jose Goldemberg, Thomas B. Johansson, Amulya Reddy, and Robert H. Williams, and *Renewable Energy: Sources for Fuels and Electricity*, edited by Thomas B. Johansson, Henry Kelly, Amulya Reddy, and Robert H. Williams. This draft was edited by Rosemarie Philips.*

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## **SUMMARY**

Energy is central to current concerns about sustainable human development, affecting economic and social development; economic growth; the local, national, regional, and global environment; the global climate, a host of social concerns, including poverty, population, health, and gender-related issues; the balance of payments; and the prospects for peace. Energy is *not* an end in itself, but rather the *means* to achieve the goal of sustainable human development.

The energy systems of most developing countries are in serious crisis involving insufficient levels of energy services, environmental degradation, inequity, poor technical and financial performance, and capital scarcity. Approximately 2.5 billion people in the developing countries have little access to commercial energy supplies. Yet the global demand for energy continues to grow: total primary energy is projected to grow from 378 exajoules (EJ)<sup>1</sup> per year in 1990 to 571 EJ in 2020, and 832 EJ in 2050, with the developing-country share increasing from 34 percent in 1990 to 49 percent in 2020, and 60 percent in 2050.<sup>2</sup> If this increase occurs using conventional approaches and energy sources, already serious local (e.g., indoor and urban air pollution), regional (e.g., acidification and land degradation), and global (e.g., climate change) environmental problems will be critically aggravated. There is likely to be inadequate capital available for the needed investments in conventional energy sources (US\$ 100-200 billion per year in developing countries), making the lack of available energy a barrier to development.

Similarly, development assistance is in crisis as well. The amount of available assistance is shrinking, even as a number of non-traditional country claimants are emerging. In 1994, net total official development assistance financing amounted to US\$ 67.4 billion compared with US\$ 74 billion in 1986 based on 1993 constant dollars.<sup>3</sup> Moreover, the conventional approach to development assistance, based on significant use of expatriates, is becoming increasingly more expensive. A new, more cost-effective approach to development assistance is needed.

Government spending on energy must also be re-assessed. Government subsidies for conventional energy technologies are approximately US\$300 billion per year worldwide.<sup>4</sup> In 1992, subsidies in *developing countries* amounted to approximately US\$50 billion, more than official development assistance from all sources taking debt repayment into account.<sup>5</sup>

Current approaches to energy are thus not sustainable and will, in fact, make energy a barrier to socio-economic development. What is needed now is a new approach in which energy becomes an instrument for sustainable development. The two major components of a sustainable

energy strategy are 1) more efficient energy use, especially at the point of end-use, and 2) increased use of renewable sources of energy. Technologies now exist and/or are in advanced stages of development to support such a new path for energy development.

The UNDP Initiative for Sustainable Energy (UNISE) is designed to harness opportunities in these areas and to build upon UNDP's existing energy activities to help move the world, toward a more sustainable energy strategy by helping programme countries.

The activities to promote sustainable energy strategies include.

- \* mobilising support for indigenous capacity building, so that countries can identify and make use of new approaches and technological opportunities as well as train entrepreneurs and implement new financing/credit modes;
- \* encouraging countries to create a supportive legal, institutional, and regulatory climate for sustainable energy development, including an investment climate that will attract private capital;
- \* contributing to a leapfrogging strategy through innovative demonstration projects and through promoting the rapid development and dissemination of key technologies for sustainable energy development;
- \* supporting the formulation and implementation of national energy action programmes linking measures related to energy to goals in areas (poverty, jobs, environment, women) affected by energy system developments;

UNDP already provides substantial technical assistance in the field of energy. In the last two decades, UNDP has committed more than US\$ 400 million to more than 900 projects in Africa, the Asia/Pacific region, Latin America, the Arab States, and Eastern Europe. Many lessons have been learned from this experience (Appendix A). UNISE draws on these lessons and orients UNDP's energy funding toward energy activities that contribute to long-term sustainable development by taking advantage of the opportunities provided by new technologies and approaches. Energy can become an instrument for meeting all of UNDP's primary objectives -- poverty elimination, employment creation (with increasing labour productivity), the advancement of women, and environmental regeneration (Box 1).

The UNISE builds on UNDP's proven strengths: its experience in supporting indigenous capacity building, its considerable convening power, its respectability and credibility, and its

decentralised structure. These characteristics make UNDP an effective agent for sustainable energy strategies. However, UNDP cannot fund the needed activities alone. Rather, it must collaborate with governments, the private sector, other UN agencies, and non-governmental organisations.

Through UNISE, UNDP can play a catalytic role among donors and host countries. It can make energy a priority within its own funding, leverage additional funding from other sources, and provide crucial pre-investment assistance in channelling appropriate proposals to other sources.

### **A Unique Opportunity**

The current situation offers UNDP a unique opportunity to undertake actions that can effectively help alter the energy path on which much of the world is headed. The actual or near availability of new energy technologies offers the prospect of low-cost, localised solutions to national energy concerns. At the same time, system-level changes in UNDP's funding and programming -- the so-called successor arrangement -- make a whole new approach to energy possible. This new approach -- incorporated in the UNDP Initiative for Sustainable Energy -- makes energy an instrument for achieving UNDP's central goal of promoting sustainable human development. The following chapters discuss energy's links to major development issues (Chapter I); existing and emerging technological opportunities (Chapter II); the new UNDP Initiative (Chapter III); and the implementation of UNISE (Chapter IV).

***Box 1. UNDP's Overall Mission***

At its June 1994 meeting, the UNDP Executive Board commended the Administrator on his "Initiatives for Change" and welcomed the goals and priorities it proposed. The goals are (i) strengthening international co-operation for sustainable human development, (ii) helping the United Nations become a unified and powerful force for sustainable human development, and (iii) focusing UNDP's own resources on making the maximum contribution in the countries it serves to certain key dimensions of sustainable human development. The four priority areas are: (i) poverty elimination, (ii) job creation, (iii) the advancement of women, and (iv) environmental regeneration. The Board also emphasised that national development priorities shall be the primary determinants of UNDP-supported programmes, which must remain country-driven.

***The Role of Energy***

Although not explicit in any one of them, *energy* is central to the UNDP priority areas, and to current concerns about sustainable human development, affecting economic and social development; socio-economic growth; the local, national, regional, and global environment; the global climate; a host of social concerns, including poverty, population, health, and gender-related issues; the balance of payments; and the prospects for peace. Energy is *not an end in itself*, but rather the *means* to achieve the goal of sustainable human development.<sup>6</sup>

## **I. ENERGY AND ITS LINKS TO MAJOR ISSUES**

To meet socio-economic development goals, people and countries must have adequate energy services to meet the household needs of their populations as well as the needs of their productive and service sectors (Box 2). Increases in economic output, population, and urbanisation in developing countries mean that energy service requirements will inevitably increase.

Since 1970, world commercial energy consumption has grown at an average annual rate of 2.5 percent. In 1970, world primary energy consumption totalled 190 EJ annually; by 1992, it had increased to 378 EJ per year.<sup>7</sup> Under various scenarios spelled out by the World Energy Council (WEC) and International Institute for Applied Systems Analysis (IIASA), world primary energy consumption is expected to grow considerably. By 2020, consumption is projected to reach 646 EJ per year in the High Growth scenario, 571 EJ in the Middle Course scenario, and 496 EJ in the Ecologically Driven scenario. By 2050, annual consumption under these scenarios will be 1,042 EJ, 832 EJ, and 596 EJ, respectively.<sup>8</sup>

Most growth in energy consumption is projected to occur in the developing countries. In 1990, these countries accounted for 34 percent of global energy; they are projected to account for 49 percent by the year 2020. The OECD countries' share is projected to go from 47 percent to 38 percent, and that of "reforming" economies from 19 percent to 13 percent. By 2050, the developing-country share is likely to reach 60 percent.<sup>9</sup>

### **L1 Energy and Other Development Concerns**

Energy is of little interest for its own sake. It is, however, an essential ingredient of socio-economic development and economic growth, and the production and consumption of energy is often linked to other major issues in society, including poverty and socio-economic development, environmental degradation, and security challenges.

#### *Poverty and Socio-Economic Development*

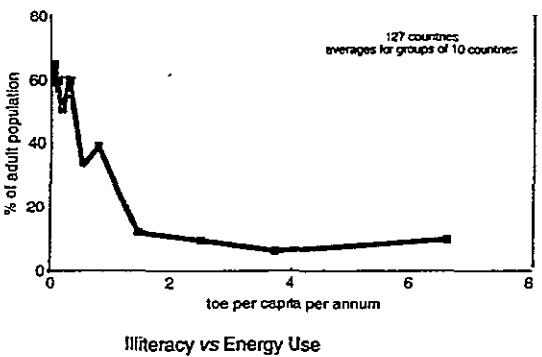
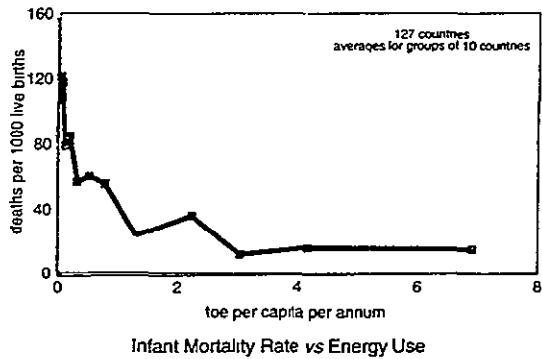
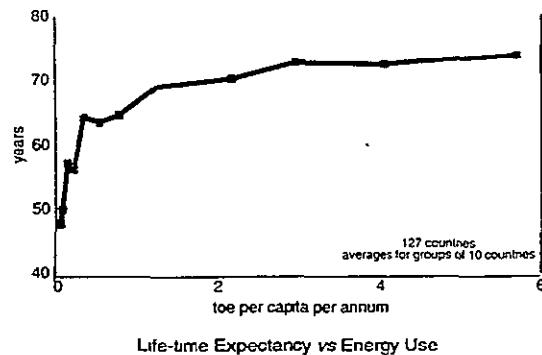
The importance of energy in socio-economic development was first emphasised in pioneering work by the Bariloche Foundation in Argentina, using the Latin American World model.<sup>10</sup> This approach was developed further to estimate the energy requirements to satisfy basic human needs.<sup>11</sup> Figure 1 shows a plot of three social indicators -- illiteracy rate, infant mortality, and life expectancy, for 127

countries in relation to commercial energy consumption per capita (used as a proxy for energy services, for which data are not available). The graphs correlate dramatic improvements in human well-being at an annual level of approximately one ton of oil equivalent per capita energy use. Because countries with the lowest energy use per capita also utilise energy much less efficiently, their relative level of energy *services* is even lower than the graphs suggest. This inefficiency is large enough to compensate for the omission of non-commercial sources of energy in Figure 1. Thus Figure 1 presents an understatement of the real situation. Socio-economic growth in developing countries will increase the demand for energy services. This will translate into higher levels of demand for primary energy, with the level of demand depending on how efficiently energy is used, especially at the point of end-use.

International experience has shown a positive correlation between access to energy and electricity services, and educational attainment and literacy among both the rural and urban poor. Families lacking adequate energy supplies will tend to limit children's time spent on schoolwork and reading; in extreme cases, families may withdraw children from school systems to spend time on fuelwood and dung collection. World-wide, girl children are disproportionately affected. The impact of female illiteracy in adult life is felt in children's health, nutrition, and family welfare in general.<sup>12</sup>

World-wide, two billion people do not have access to electricity, and two billion use fuelwood or dung for heating and cooking.<sup>13</sup> For most countries in Asia, wood energy still provides up to 50 percent of national energy needs. Even where the share of wood energy is decreasing, consumption of woodfuels (wood and charcoal) in absolute terms is still increasing. Woodfuel is very important for local economies; from various case studies, it has been inferred that for some 10 percent of the rural population in Asia, woodfuel-related activities are the main source of income<sup>14</sup>. On the positive side, the wood energy sector, as well as other renewable energy sectors, offers potential (new) employment opportunities for rural people.

In general, the poor pay a higher price for the minimal energy services they utilise. The monetary price represents a high real economic cost when compared to disposable family income. In addition, the poor pay a higher price in the form of time spent to obtain energy, especially by women; higher economic costs at both the household and national level; and high levels of pollution and poor health.



### *Energy Consumption Figure 1. Life Expectancy, Infant Mortality, and Literacy as a Function of Commercial Per Capita in 127 Countries*

*Note:* Non-commercial or traditional fuels are not included. These usually refer to fuelwood, bagasse, and animal and vegetable wastes; they make a significant contribution to total energy consumption in a number of developing countries.

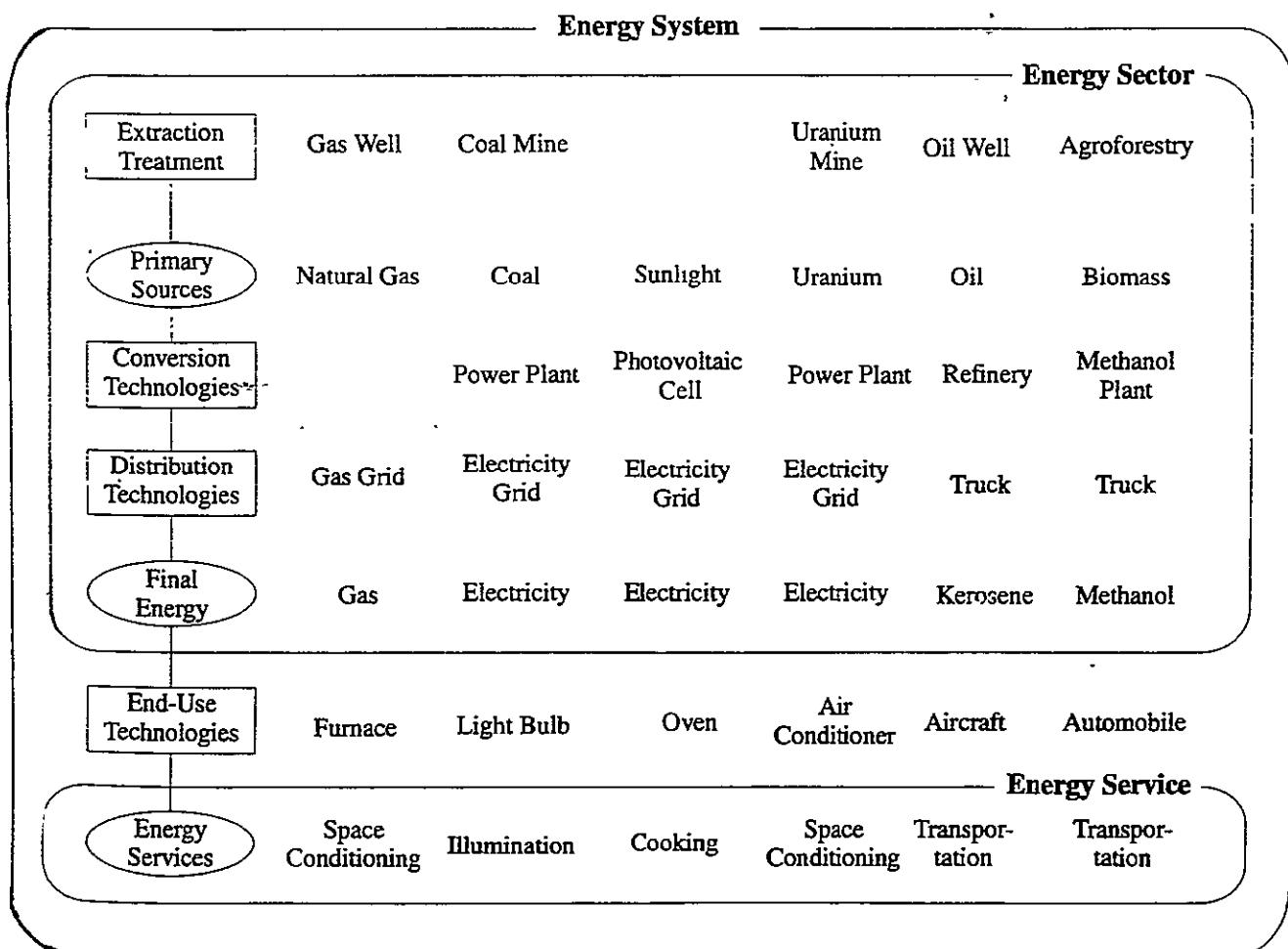
*Sources:* World Energy Council, *Energy for Tomorrow's World* (London: Kogan Page Ltd., 1993); and J. Goldemberg (unpublished).

**Social and Gender Impact of Scarce Energy Services.** Women are particularly affected by lack of adequate energy services. Poor rural women and children may spend four to six hours travelling seven to ten kilometres and collect only enough firewood for one day's cooking and heating needs for a household of four to five persons.<sup>15</sup> The time women spend collecting firewood detracts from the time they are able to spend caring for their children, performing agricultural tasks, or engaging in income-generating activities. In both rural and urban areas, women who are heads of households face particularly severe difficulties in obtaining energy services. In rural areas, female heads of households have more tasks to undertake and either less money to purchase fuel (due to wage differentials) or less time with which to gather fuels. In urban areas, female-headed households generally have lower incomes and need to devote a larger fraction of their limited income to obtaining energy services. Energy strategies that recognise opportunities to provide rural energy services could advance both the Rio and Beijing agendas.<sup>16</sup>

**Box 2. Energy Services**

The objective of the energy system is to provide these services begins with the collection or *energy services*. Energy services are the desired and useful products, processes, or services that result from the use of energy, for instance, illumination, comfortable indoor climate, refrigerated storage, transportation, appropriate temperatures for cooking, materials, etc. The energy chain to deliver extraction of primary energy which is then converted into energy carriers suitable for the end use(s). These energy carriers are used in energy end-use technologies to provide the desired energy services (Figure 2). Thus far, most discussions of the energy sector have focused on supply-side issues. However, the energy system involves much more than what is conventionally considered the energy sector and unless the scope of discussions about energy is extended, energy end-use efficiency will receive less attention than it deserves.

**Economic Costs.** Poor people normally spend a higher fraction of their disposable income on energy than other groups, both because their appliances and fuels are less efficient and because they are forced to purchase fuel in smaller amounts. They also tend to benefit less than middle- and upper-income households from subsidy programmes. For example, because the rural and urban poor have limited access to electricity, they cannot benefit from household tariff subsidies meant to guarantee their basic needs. Similarly, kerosene subsidies benefit wealthier households able to purchase the fuel and appliances necessary to use the kerosene more than the poorest households, who benefit little, if at all.<sup>17</sup>



*Figure 2. The Energy System: From Primary Sources of Energy to Energy Services*

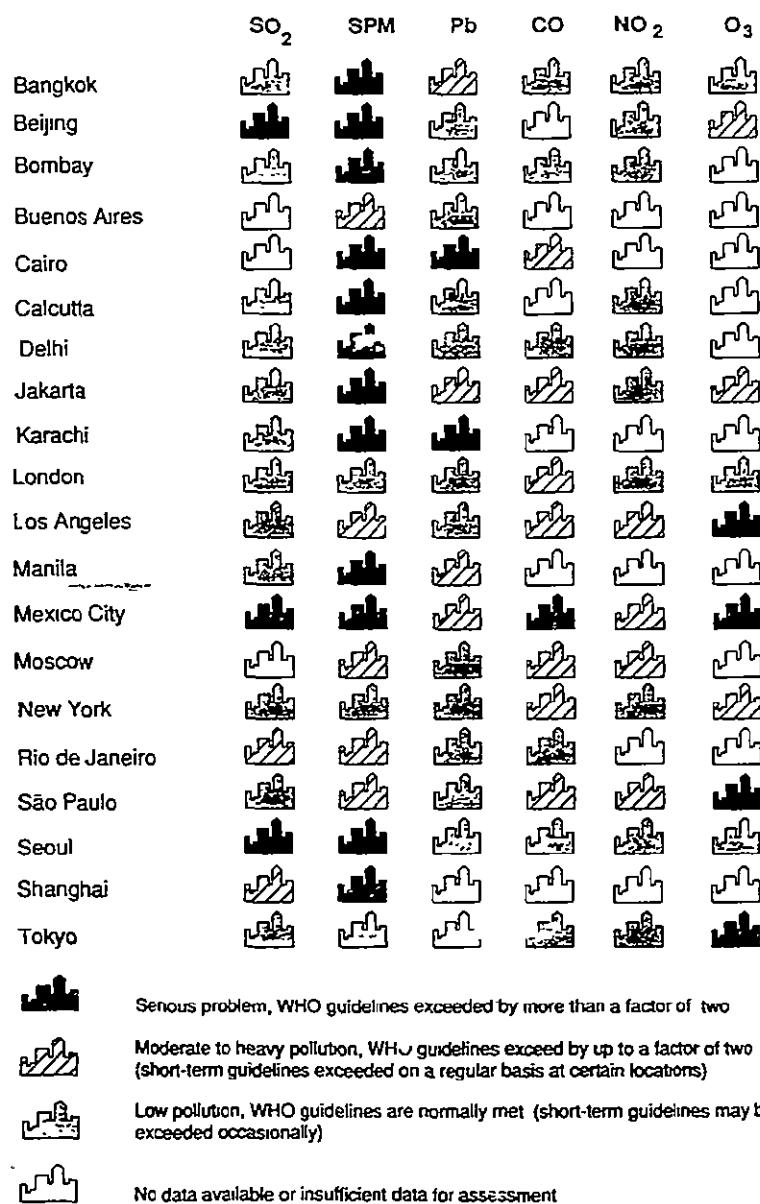
Source: N. Nakicenovic, et.al. "Energy Primer", pp. 77, R. Watson, M. Zinyowera and R. Moss (eds.), *Climate Change: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report*, (New York: Cambridge University Press, 1996).

Poverty and energy are also related at the macro-economic level: a) through the high foreign exchange costs of oil and other fossil fuel imports borne by developing countries, and b) through the lack of available investment capital for the energy sector.

*Oil import expenditures* In the early 1980s, the costs of oil imports by oil-importing developing nations often amounted to more than half their export earnings. The situation improved with the lowered oil prices in the mid 1980s, but for some countries, oil imports still correspond to a large fraction of export earnings. Oil price fluctuations in general represent a continued source of instability for developing-country current account balances.

*Capital availability.* The World Bank has estimated the capital investment needs of the energy sector during the 1990s to be approximately US\$ 100 billion annually for the electricity sector in developing countries alone, with about 40 percent required payment in foreign exchange.<sup>18</sup> In 1995, the World Energy Council estimated that energy investment requirements in developing countries between 1990 and 2020 will be US\$ 3-7 trillion (1990\$), of which some 70 percent will be needed for electric power. To reach this, average annual investments of US\$ 100-US\$ 200 billion will be needed, increasing from approximately US\$80 billion per year during the period 1990-95 to US\$ 140-US\$ 300 billion per year in the period 2015-2020. However, under the WEC Ecologically Driven scenario, investment requirements to achieve the same economic growth would be considerably less -- US\$15 billion per year less during 1990-95 and US\$60 billion per year less by 2015-20.<sup>19</sup>

*Health Costs.* Urbanisation trends are largest in developing countries, where most new megacities will occur in the next ten to twenty years. In many urban areas, emissions create poor air quality. The air pollution situation in twenty megacities (of which, sixteen are in developing countries) was measured along six indicators (sulphur dioxide, solid particulate matter, lead, carbon monoxide, nitrous dioxide, and ozone). Of these 120 cases, 46 registered as either "serious problems" (defined as exceeding WHO guidelines by a factor of more than two) or "moderate to heavy pollution" (defined as exceeding WHO guidelines by a factor of up to two, with short-term guidelines exceeded on a regular basis) (Figure 3.) Most developing country megacities regularly have air pollution levels well above WHO guidelines, and this situation is getting worse.<sup>20</sup> The health implication of air pollution exposure in developing countries has been reviewed by K.S. Smith.<sup>21</sup>



*Figure 3. Overview of Air Quality in Twenty Megacities* (based on a subjective assessment of monitoring data and emissions inventory).

Source: United Nations Environment Programme and the World Health Organisation, *Urban Air Pollution in Megacities of the World* (Oxford: Blackwell Publishers, 1992).

Some air pollutants are carcinogenic, cause acid rain, and have significant health effects. They impair human respiration, affect the nervous system, and cause dizziness, slowed reflexes, and respiratory diseases. The pollutants are potentially more damaging together than individually.<sup>22</sup>

Transportation is a major cause of the high levels of air pollution. With projected increases in population and urbanisation -- accompanied by increases in transportation and congestion -- the situation is likely to deteriorate unless specific action is taken. What is needed are not small changes at the margin, but major efforts to meet the challenge of increased urban population growth and growth in per capita demand for energy services. California and other US states have passed legislation requiring the rapid introduction of ultra-low and zero-emission road transportation vehicles.<sup>23</sup>

The inefficient burning of coal, charcoal, and biomass contributes to poor indoor air quality. The human exposures to air pollution from stoves in fairly unventilated homes or in enclosed courtyards often exceed recommended World Health Organisation levels by factors of ten, twenty, or more.<sup>24</sup>

### *Environmental Degradation*

Energy production and use can impact negatively on the environment by contributing to land degradation, acidification and global warming.

***Land Degradation.*** The consumption of woody biomass for cooking and heating, especially the felling of trees for fuelwood and charcoal delivery to cities, has contributed to land degradation. Use of non-woody biomass, such as stalks, husks, and other agricultural residues contributes to loss of agricultural productivity through reducing nitrogen to the soil cycle. Energy is seldom the main cause of deforestation; other factors, particularly land clearance for agriculture and commercial timber production, are much more important. Finally those countries for which coal is an important energy source, face land management problems related to waste heap management; additional problems often exist for waste water management as a result of coal production and preparation.

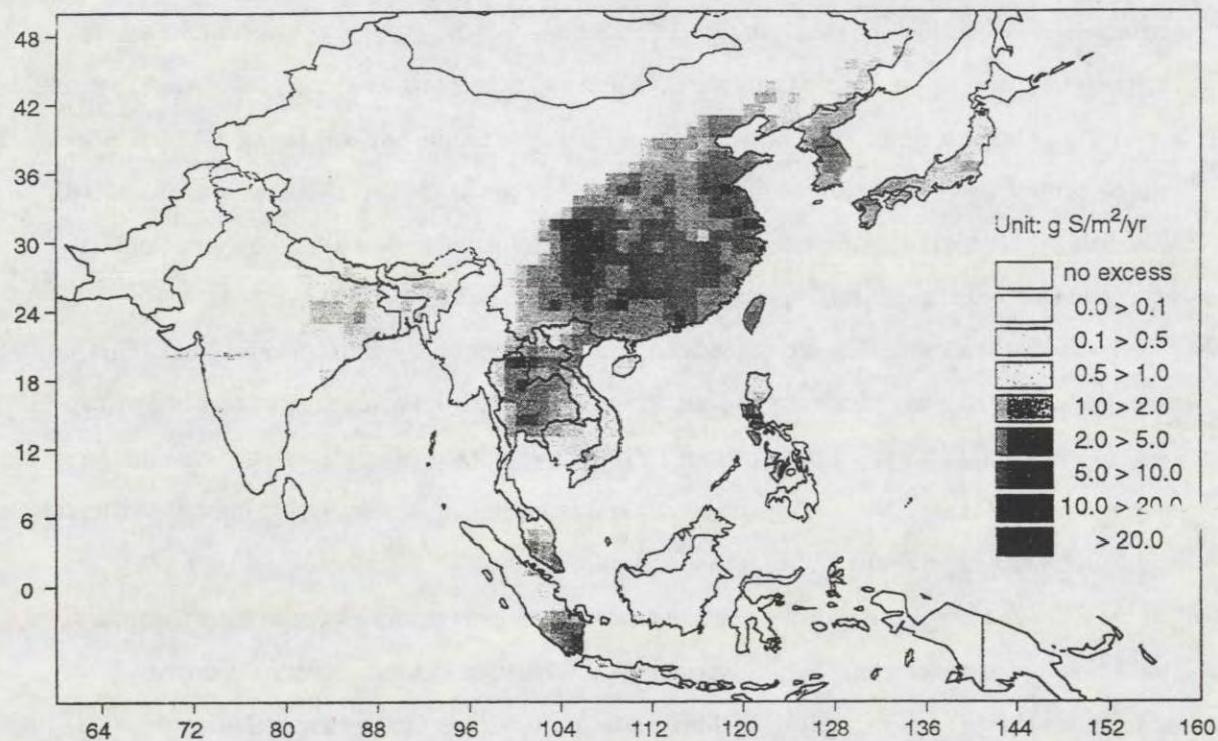
***Acidification.*** Combustion of sulphur-containing fuels leads to the formation of sulphur oxides; when these are emitted into the atmosphere, they lead to acid depositions on land and water, often far from their original source. Nitrous oxide formed during combustion also contributes to the acid depositions. In combination with air pollution, the deposition of acid substances has caused

serious forest damage in large parts of Europe. Some forests are dying, and many surface waters are becoming acidified, often leading to high concentrations of aluminium. Crop losses attributable to acidification of water and land represent threats to food security in many developing countries. It is now becoming clear that the conventional combination of fuel cleaning and in-plant technical improvements cannot result in the emissions reductions needed to reduce depositions below the "critical load" levels for large areas in Europe, indicating that measures at the level of the whole energy system are required. Acid deposition is a growing concern in other parts of the world as well; however, most developing countries lack access to adequate technology and capital for conventional sulphur control devices. The situation is particularly dramatic in the rapidly growing economies of Asia. In a hypothetical scenario with no sulphur abatement, sulphur depositions in South and East Asia would exceed critical loads in most parts of the region by 2050 (Figure 4).<sup>25</sup>

***Global Warming.*** The increased atmospheric concentrations of greenhouse gases (GHGs) are expected to result in global warming, according to the scientific assessments published by the Intergovernmental Panel on Climate Change (IPCC).<sup>26</sup> The potential effects of such climate change include a rise in the sea level; increased severity and frequency of storms, altered rainfall distribution, etc., with developing countries hit first and hardest.

Climate change is a growing concern among developing countries due to fears of agricultural production loss and increased seasonal variability, soil changes in some zones and increased vulnerability due to unpredictability of climate change impact. Other concerns relate to the vulnerability of low lying coastal and delta areas due to sea level rises.<sup>27</sup> This possibility is an important reason for developing and utilising low carbon-dioxide-emitting energy options that simultaneously advance overall development objectives. However, resource constraints in developing countries limit the ability to address emissions based on current carbon-based technology paths.

The objective of the United Nations Framework Convention on Climate Change (FCCC) is to achieve "stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner."<sup>28</sup>



**Figure 4. Excess Sulphur Deposition in Asia Above Critical Loads in a "Business-as-Usual" Scenario**

Source: World Energy Council (WEC) and International Institute for Applied Systems Analysis (IIASA), *Global Energy Perspectives to 2050 and Beyond* (1995), p.85.

What levels of greenhouse gas concentrations are needed to meet that objective and when it can be reached are subjects of continuing intergovernmental negotiation? The most important GHG is carbon dioxide, whose atmospheric concentrations result primarily from the combustion of fossil fuels. According to the 1994 IPCC report, to stabilise atmospheric carbon dioxide concentrations at a level less than three times that of the pre-industrial era, emissions will have to be reduced below the 1990 level within the next hundred years or so. If even lower levels of atmospheric carbon dioxide concentrations are required, emissions will have to be reduced by more and faster (Figure 5).<sup>29</sup>

Under current projections, however, world emissions of carbon dioxide from the use of fossil fuels are projected to *increase* from 6.0 billion tonnes of carbon (6.0 GtC) in 1990 to somewhere between 6.3 and 10.0 GtC in the year 2020 under various World Energy Council scenarios.<sup>30</sup> Since 78 percent of the world's primary energy comes from fossil fuels, reducing emissions as much as needed will require major changes in the world's energy system. OECD countries have contributed most of the build-up of carbon dioxide. Today, however, developing countries emit about the same amount of carbon as OECD countries.

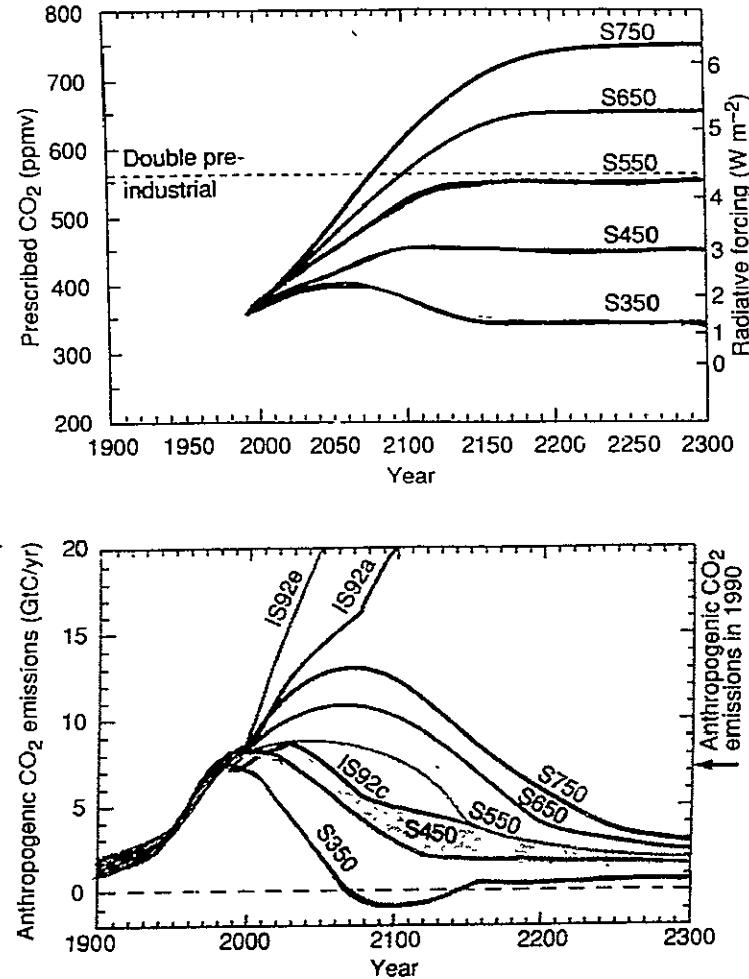
### *Security Concerns*

Two energy-related security issues stand out: a) the available supply of oil, and b) the connection between nuclear energy and the risks of nuclear weapons proliferation.

In 1990, 40 percent of the world's commercial primary energy supply was provided by oil, 23 percent by natural gas. World oil reserves , that is, the oil discovered to date that can be delivered to markets at current oil prices, are estimated to be able to support production at the current rate for 43 years; reserves of natural gas can support production at the current rate for 65 years. The Middle East has 66 percent of oil reserves and 32 percent of natural gas reserves.<sup>31</sup>

Oil production in the non-OPEC countries is estimated to be at its peak now, with a projected 10-20 percent decline by the year 2010. A projected increase in oil consumption would thus lead to increased dependence on OPEC oil. For example, the US National Energy Strategy (1990) estimates that US oil imports will grow from 46 percent of US oil consumption in 1990 to 62 percent in the year 2000 and 80 percent in the year 2030.<sup>32</sup>

Dependence on oil resources that are not widely distributed around the world has created strategic economic interests in oil, which have lead to political crises, economic vulnerability, and



**Figure 5. Profiles of Anthropogenic Emissions of CO<sub>2</sub> in Various Scenarios**

**Note:** The upper figure shows profiles of atmospheric CO<sub>2</sub> concentrations leading to stabilisation at 350, 450, 550, 650 and 750 ppmv. Double pre-industrial CO<sub>2</sub> concentration is 560 ppmv. The radiative forcing resulting from the increase in CO<sub>2</sub> relative to pre-industrial levels is marked on the right hand axis. Note the non-linear nature of the relationship between CO<sub>2</sub> concentration change and radiative forcing. The lower figure shows illustrative anthropogenic emissions of CO<sub>2</sub> leading to stabilisation at concentrations of 350, 450, 550, 650 and 750 ppmv following the profiles shown above (using a mid-range carbon cycle model). The range of results from different model is indicated on the 450 ppmv profile. The emissions for the IS92a, c and e scenarios are also shown in the figure. The negative emissions for the stabilisation at 350 ppmv are an artefact of the particular concentration profile imposed.

**Source:** Intergovernmental Panel on Climate Control (IPCC), *Radiative Forcing of Climate Change: The 1994 Report of the Scientific Assessment Working Group of IPCC – Summary for Policy Makers* (1994), p.15.

military conflict. The world may be moving toward an international oil situation similar to the early 1970s, when there was a strong dependence on Middle East exports.

Another important security issue is the extent to which widespread use of nuclear energy increases the risks of nuclear weapons proliferation. Uranium-fuelled reactors produce approximately 200 kg of plutonium per year. An explosive similar to the Nagasaki bomb can be produced with only about 4 kg of plutonium when using advanced designs.<sup>33</sup> Unsafe operation and maintenance of nuclear power plants in many countries pose threats to human health and welfare that go beyond national borders.

## I.2 Current Approaches Unsustainable

As illustrated by issues raised in the previous sections, the linkages between poverty and socio-economic issues, environmental degradation, security concerns, and the energy sector call into question the path of energy sector development. The linkages between social concerns and the energy sector -- and the already serious poverty and environment problems confronting the world today -- make the current path of energy system development unsustainable. Current levels and patterns of energy consumption cannot be sustained, much less spread more widely, as today's developing countries pursue their development goals.<sup>34</sup> Agenda 21 states well that energy will either hamper other development objectives or, if handled wisely, contribute to meeting them.

"Energy is essential to economic and social development and improved quality of life. Much of the world's energy, however, is currently produced and consumed in ways that could not be sustained if technology were to remain constant and if overall quantities were to increase substantially. The need to control atmospheric emissions of greenhouse and other gases and substances will increasingly need to be based on efficiency in energy production, transmission, distribution and consumption, and on growing reliance on environmentally sound energy systems, particularly new and renewable sources of energy."<sup>35</sup>

Poverty eradication and improved living standards cannot be achieved sustainably without major changes in the current energy system. A new paradigm is needed for energy system development that builds on more efficient use of energy and increased utilisation of renewable energy

sources. Because the transition to this new paradigm will inevitably take many decades, it is also necessary in the interim to use fossil fuels in a cleaner way and to use natural gas rather than oil whenever possible.

Improvements in end-use efficiency and greater use of renewables have long been discussed as major hopes for the future. They have not yet, however, made the substantial contribution to increased energy services for which they have potential. Is it realistic to think that they can now support a new paradigm and the level of change that is required? The next section outlines existing and emerging technological opportunities.

## **II. NEW TECHNOLOGIES, NEW POSSIBILITIES**

Producing the level of energy services needed in the developing world cannot be done sustainably with minor adjustments to the conventional energy system. What is required instead is a major shift away from current approaches toward new ways of providing energy services-- ways that contribute to, rather than hinder, development. The technological possibilities today are considerable.

Technologies that improve energy efficiency, utilise renewable sources of energy, and use conventional fuels more cleanly all have significant potential. These are the options that must be developed and utilised further in order to advance along a more sustainable energy path.

During the last decade, technological developments and operating experiences have made many technologies (particularly those utilising renewable energy) more mature and competitive, creating many new opportunities. What is needed now is to identify existing and potential opportunities and to design policies and other measures to capture their benefits. To take advantage of these new opportunities the following activities are needed: conducting and promoting demonstration projects to illustrate the technologies' potential and cost-effectiveness, utilising existing markets, and building up new markets. These steps will facilitate large-scale dissemination of renewable energy technologies. In addition, continued research and development is needed to improve some technologies still further.

### **II.1 Technologies to Improve End-Use Energy Efficiency**

In most parts of the world today, conserving a kilowatt hour (kWh) of electricity or fuel is cheaper than producing an additional kWh. As a result, sustainable energy development strategies need to focus on improving the efficiency of present and future energy use. This would reduce the amount of energy required to provide needed energy services and still be profitable, as well as reduce emissions since less primary energy would be required for obtaining the same energy service.

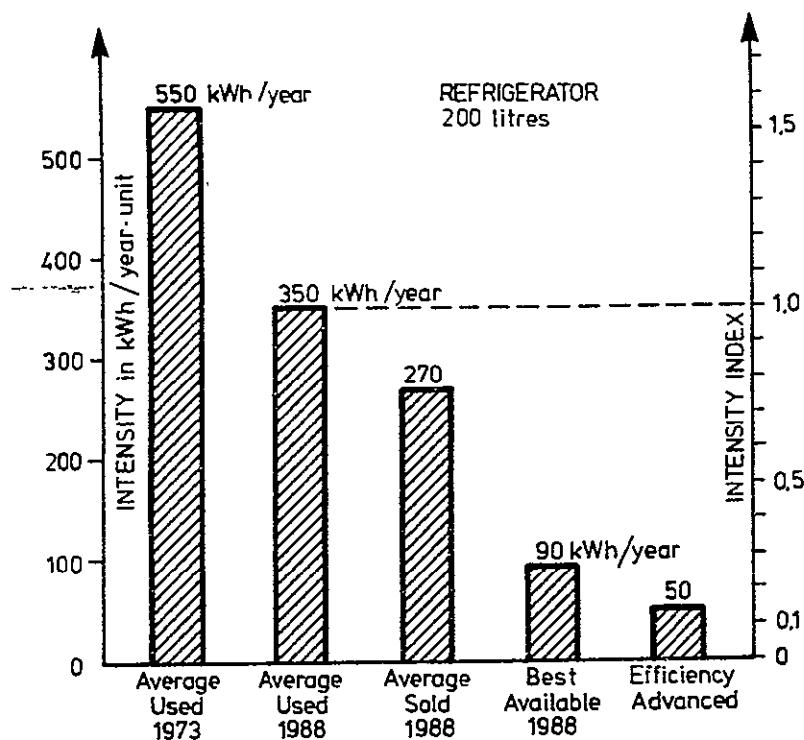
Instead of focusing planning on gross supplies to the various consuming sectors, energy planners should use integrated resource planning (IRP) to identify the lowest-cost means of performing energy services. IRP includes evaluating demand and supply side technology options for achieving given energy service goals at least cost. As investments are made, there is opportunity to build higher levels of energy efficiency into the entire economy -- through more energy-efficient basic materials industries, improved building design, more energy-efficient transport systems, and

improved manufacturing processes. For rapidly growing economies, this emphasis on the energy efficiency of the capital stock will determine sectoral energy requirements well into the next century. For example, with a 10 percent annual growth rate of investment in capital stock, the total capital stock will double within seven years. If energy-efficient technologies and equipment are introduced now, the energy requirements can be dramatically reduced from what they will be if the capital stock is built utilising existing technologies, methods, and equipment. For *newly installed facilities using improved technologies*, the energy savings can range from 50 to 90 percent of current consumption (per unit output).<sup>36</sup>

Existing buildings, equipment, and installations can be made more energy efficient by so-called retrofitting. It is often cost effective to replace, for example, incandescent lightbulbs with compact fluorescent lightbulbs, and there are many opportunities to reduce total cost and energy consumption at the same time. Experience shows that *retrofits and energy-efficiency improvements to existing facilities* can result in energy savings of 20 to 50 percent of current consumption (per unit output) (Figure 6 illustrates this for refrigerators). In Pura Village in south India, household expenditure for lighting was cut in half even though illumination increased by a factor of about nineteen and energy inputs decreased to one-ninth of what they were when kerosene was used.<sup>37</sup>

The levels of energy services provided are much lower than the levels of services obtainable from the same amount of energy in the industrialised countries because efficiencies are much lower. This is especially the case for non-commercial biomass energy. In fact, analysis shows that by shifting to high-quality energy carriers and by exploiting cost-effective opportunities for more efficient use of energy, it would be possible to satisfy basic human needs and to provide considerable further improvements in living standards without significantly increasing per capita energy use above the present level. For instance, the energy requirements for today's developing countries to have the West European standard of living of the 1970s could be as low as 1 kW/cap, which is only about 20 percent higher than the 1986 level in developing countries. This remarkable result could be obtained because energy (especially traditional sources of energy) is currently used so inefficiently and because modern cost-effective energy end-use technologies could significantly increase energy efficiency. With a development path that makes use of strong-performance energy-efficient technologies, energy supply need not become a constraint on development. Of course, total energy use would grow somewhat faster than population growth, and electricity demand would grow faster than total energy. In the 1kW per capita scenario, primary energy use in developing countries

increases from 1.11 kW/cap in 1980 to 1.24 kW/cap, and electricity consumption increases from 39 watts to 210 watts per capita. In fact, the shift to electricity is to a large extent responsible for the fact that primary energy use does not go up much because of the better opportunities for energy end-use efficiency improvement when electricity is the energy carrier.<sup>38</sup>



*Figure 6. Energy Efficiency of Refrigerators (kWh/per unit/per year)*

*Note:* Stock average performance improves as newer, more efficient models penetrate. Opportunities exist to speed up the process of technology development and penetration in the capital stock. The data are from Denmark. G.Dutt has recently reviewed the field of energy-efficient and environment-friendly refrigerators. (G. Dutt, 1995, "Energy -efficient and environment-friendly refrigerators," *Energy for Sustainable Development*, Vol. 1, No. 5, pp. 57-67.)

*Source:* J.S. Nørgård, "Low Electricity Appliances: Options for the Future," in T.B. Johansson et al. (eds.), *Electricity -- Efficient End-Use and New Generation Technologies and Their Planning Implications* (Lund, Sweden: Lund University Press).

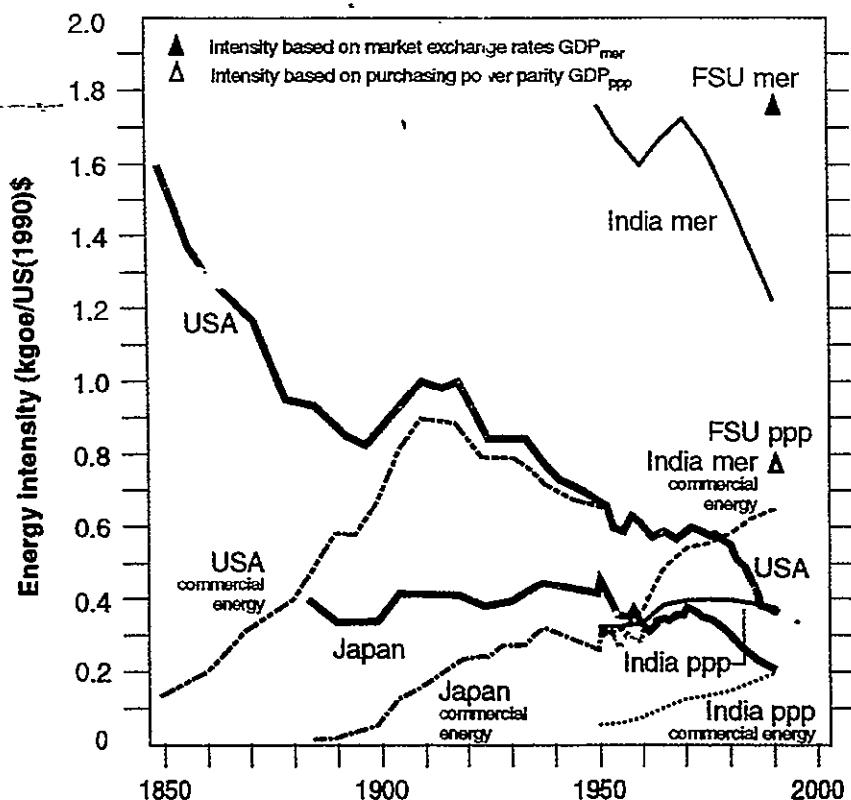
The combined effects of efficient use of energy and materials<sup>39</sup> and structural changes offer significant opportunities for cost-effective delivery of energy services and for limiting energy growth. Materials use is important because most of the energy used in industry is for the production of basic materials such as metals, cement, chemicals, and paper. Figure 7 shows energy intensities for selected countries. In the United States (as in other industrialised countries), energy efficiency improvements take place continually on an economy-wide scale. Energy intensities are reduced because of better technologies and structural shifts in the economy toward less-energy-intensive activity. For example, as wealth increases, consumption shifts from materials-intensive products to knowledge-intensive products; these contain fewer kilograms of materials per unit of service or consumer product and thus contribute to reducing total energy demand. At the same time, the performance of the materials themselves is increasing, reducing the amounts of material (and therefore energy) required for a given task.

Comparing energy intensities between different economies is a difficult task. Ideally, the energy intensity should be obtained from dividing the total consumption of energy by the total production of goods and services (measured in monetary units). Approximations are necessary for both factors, and the comparison of currencies is not straightforward. The outcome of comparisons between developed and developing countries is affected by the conventions used. For example, using purchasing power parity instead of market exchange rates, India is as energy efficient as the United States; however, the values of goods and services are incompletely and differently measured, since a larger fraction of the total is outside the formal economy in India than in the United States and non-commercial energy plays a larger role in India, illustrating the difficulties of such comparisons.

Currently, energy efficiency opportunities are utilised only to a limited degree in all countries, in part because energy prices generally do not reflect the full costs of energy provision. First, prices do not take account of such subsidies to conventional energy as tax breaks, favourable depreciation rules, insurance arrangements, etc. Second, they do not take account of such external effects as environmental impact. If energy prices reflected true costs, it would help to achieve the cost-effective balance between making demand-side efficiency improvements and increasing the supply of energy. However, prices are not the only barriers to efficiency improvements. Other barriers include a) lack of access to information about efficiency issues by all those making energy decisions, from designers of systems to end users; b) lack of available capital for efficiency improvements on conditions similar to those for energy supply investments; and c) the problem that

investors (e.g., landlords) may get little benefit from an energy efficiency investment in situations where the benefit is collected by another party (e.g., tenants).<sup>40</sup>

In addition to the price and non-price barriers mentioned here, there may be additional types of structural or institutional restraints to the dissemination of renewable energy and the promotion of demand-side efficiency. Known as “non-market barriers,” these restraints typically refer to lack of access to information on modern energy technologies; incomplete institutional arrangements within national state and non-state sectors (quite often related to processes of market transition or structural adjustment); weak institutional or human capacity to adopt new technologies or approaches once introduced; as well other non-price issues commonly at play in developing countries.



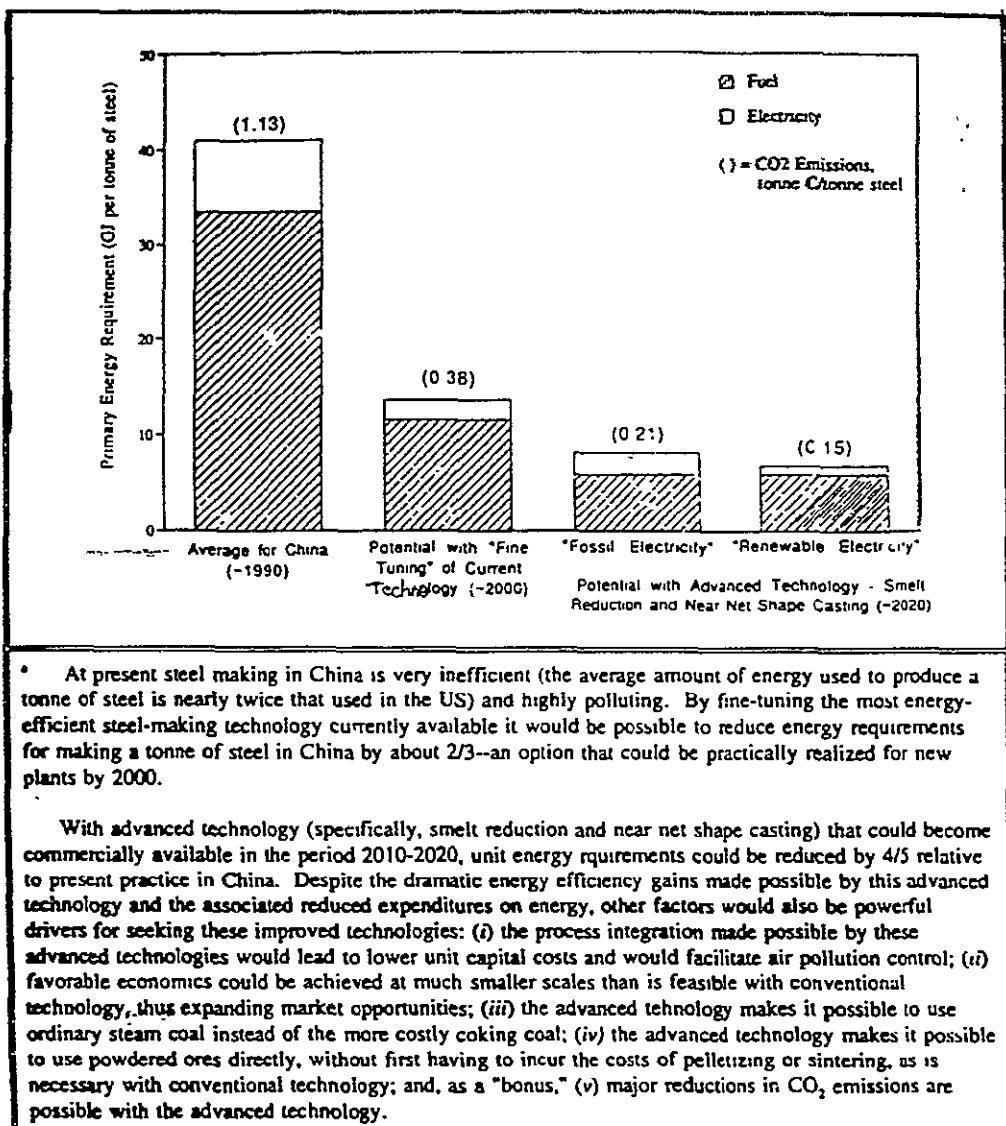
*Figure 7. Primary Energy Intensities Over Time in Selected Countries*

Source: World Energy Council (WEC) and International Institute for Applied Systems Analysis (IIASA), *Global Energy Perspectives to 2050 and Beyond* (1995).

Despite these barriers, significant reductions in energy use can be achieved by using the most efficient technologies available today. Developing countries, in particular, have the opportunity to "leapfrog" the stages of technology through which the industrialised countries moved, and to employ the present and next generations of energy-efficient and other technologies. The costs of improved energy efficiency typically are more than offset by reductions in the costs of energy. From a country's point of view, energy efficiency improvements are even more economical than supply expansion when such external costs as environmental degradation are considered.<sup>41</sup> The potential for further efficiency improvements through continued research and development is considerable. In the meantime, technology demonstration projects utilising already existing technologies could help persuade reluctant decision makers of the potential to improve energy efficiency. Examples of areas in which such projects could be particularly useful include commercial buildings and the steel industry.

Rapid construction of *commercial buildings* in many developing countries contributes to total electricity use and to peak utility demand. To make full use of cost-effective opportunities, available energy-efficient technologies for such purposes as cooling/heating, lighting, ventilation, appliances, and equipment must be integrated into the total energy systems of both new and existing buildings.

Improving energy efficiency in the *steel industry* and other energy-intensive basic-materials industries is an urgent issue in many developing countries. Several international steelmaking firms have new, clean, energy-efficient technologies that so far have operated on only a pilot or demonstration scale. Steel demand in industrialised countries is growing much slower because consumption patterns are changing and because the availability of higher performance steels means less steel is required. Thus in industrialised countries, the industry is investing little in new capacity. In developing countries such as China, however, where demand for steel is growing rapidly, the need and potential for energy-efficiency improvements are large (Figure 8). Introduction of the new technologies that were developed for, but not widely used by, the steel industry in the industrialised countries could make a significant difference in total energy used.



*Figure 8. Energy Requirements for Producing Iron and Steel with Alternative Technologies*

Source: E. Worrell, *Advanced Technologies and Energy Efficiency in the Iron and Steel Industry in China*. Paper presented at the Workshop on Advanced Iron and Steel Making Technologies, sponsored by the China Council on International Co-operation for Environment and Development, Beijing, 1995.

## **II.2 Renewable Energy Technologies**

Most renewable energy derives either directly or indirectly from the sun: solar energy creates the wind, heats the earth, evaporates the water which falls as precipitation, and provides the energy utilised in biomass production. Renewable energy now provides about 20 percent of all the primary energy people use, most of it as biomass and hydropower.<sup>42</sup> Renewable sources of energy have the potential to meet the major part of the world's demand for energy services. They are often beneficial for local and regional environmental problems such as urban air pollution and acid rain. Some renewable energy technologies, especially biomass, contribute to rural income and employment generation.

Technological innovations of the last decade are now ready to tap various renewable energy sources. Examples include coal and biomass gasification technology, gas turbine technology, production of liquid and gaseous fuels from biomass, approaches to handling intermittent generation of electricity, wind energy utilisation, electricity generation with photovoltaic and solar thermal electric technologies, fuel cells for transportation and power generation, and hydrogen as a new energy carrier, produced first from natural gas and later from biomass, coal, and electrolysis.<sup>43 44 45 46</sup>

<sup>47</sup>

A growing number of renewable energy technologies are now becoming competitive, including modernised biomass, wind energy, and solar energy. Geothermal energy, and mini- and micro- hydropower are also important energy supply options, although they have geographic limitations. However, the useful potential of these possibilities is less than the technical potential would suggest; because social and environmental concerns reduce the possibilities of exploiting the technical options.

*Wind power* Technological developments as well as improved maintenance organisation for large wind power stations has reduced cost to the level of 4 to 5 cents/kWh in windy areas, competitive with new power plants using fossil fuels. A wind power industry is now emerging in the work. The total installed capacity in the world was 3,100 MW<sub>e</sub> at the end of 1993. Over 600 MW<sub>e</sub> were added in 1994, 1/5 of which in developing countries. Many developing countries have large wind resources that can be exploited, both for large wind power plants and for decentralised electrification.

*Biomass* The prospects are particularly good for generating electricity from biomass (Figure 9). Biomass contributes about 15 percent of the world's primary energy, most of it used inefficiently as traditional energy in developing countries and causing serious indoor air pollution. Now, however,

technologies are becoming available to convert biomass resources to modern energy carriers such as electricity, and liquid and gaseous fuels, making it possible to use biomass much more efficiently and cleanly. Modernising biomass will have benefits in both the rural and the modern sectors of developing societies.

Biomass is used for co-generation of heat and power in Scandinavia, U.S. and some other European and developing countries in the forest and agricultural industries, using steam-turbine technology. With the application of modern technology for co-generation of heat and power, the sugar cane industries in developing countries could become major power producers (Figure 10). In fact, the projected potential for sugar-cane-based power generation in developing countries in year 2027 is larger than the total amount of electricity generated in developing countries today.<sup>48</sup>

Biomass can also be used to produce liquid and gaseous fuels. Brazil is pursuing this approach in its ethanol programme, which provides about one half of Brazil's automotive fuel; this programme has helped to create higher quality, reduce migration to large urban areas, and increase the overall quality of life in many small towns (Box 3).<sup>49</sup>

*Box 3. Creating Jobs through Bioenergy Plantations in Brazil*

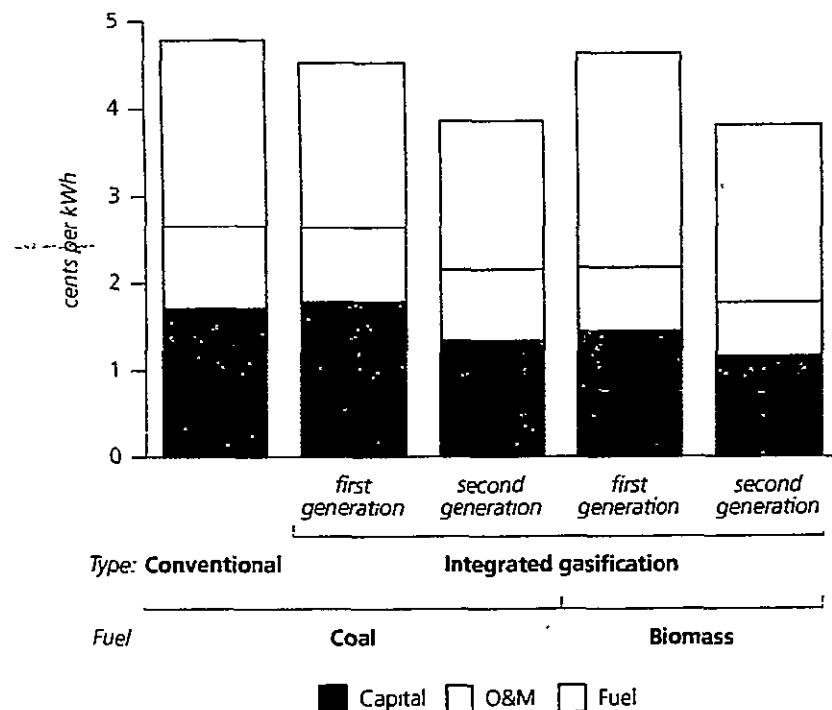
Biomass as a source of energy offers many advantages: it reduces air pollution and carbon dioxide, can be grown on a sustainable basis, and can be converted to fuel or electricity with great efficiency. In Brazil, where fuel ethanol is produced from sugar cane on a widespread basis, bioenergy production also contributes significantly to job creation.

In an attempt to reduce Brazil's dependence on imported fuel, as well as to stabilise sugar prices, Brazil introduced a programme in 1975 to substitute sugar-cane-based ethanol for gasoline in passenger cars. Today, the program is "one of the largest commercial efforts to convert biomass to energy anywhere in the world." Fuel for cars and other light vehicles is either neat-ethanol (i.e., 94 percent ethanol, 6 percent water) or gasohol (78 percent gasoline, 22 percent ethanol). The program is considered highly successful: it has reduced dependence on oil imports, stabilised sugar cane prices by creating ongoing domestic demand, promoted growth in the sugar cane industry, reduced automobile pollution, and contributed significantly to job creation – accounting for an estimated 700,000 rural skilled and unskilled jobs. It has also created a strong agro-industrial system, with a significant number of additional indirect jobs.

The cost of ethanol is presently higher than the world market price for gasoline. However, this comparison does not include the value to society of rural jobs and import reduction. There are also major opportunities for cost reductions, e.g. by increasing the amount of electricity generated by using modern technology and by increasing the use of the sugar cane residues.

*Source:* Isaias de Carvalho Macedo, "Converting Biomass to Liquid Fuels: Making Ethanol from Sugar Cane in Brazil," in Jose Goldemberg and Thomas B. Johansson (eds.), *Energy as an Instrument for Socio-Economic Development* (New York: UNDP, 1995), pp. 107-111.

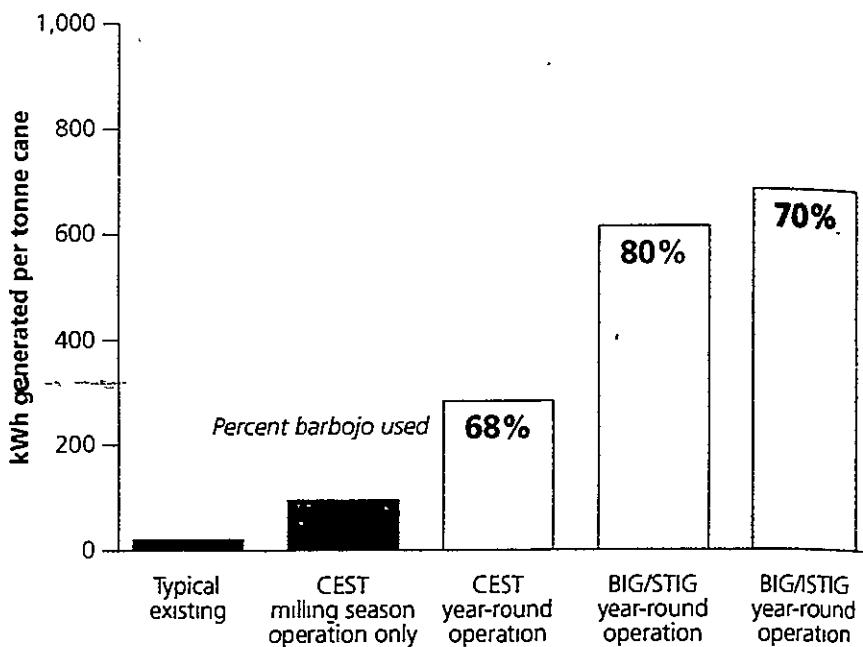
Biomass can also be gasified to provide a clean fuel for lighting, cooking , and power generation. Anaerobic digestion of manure and crop residues is used in the rural areas of some developing countries to produce a gaseous fuel, biogas. They provide by-products such as fertilisers, feed for pig and fish farms, and human health improvements. The potential for future applications is large if local expertise is built up to ensure reliable operation, and if communities are involved.<sup>50 51</sup>



*Figure 9. Projected Cost of Electricity from Coal and Biomass Using Modern Gasification and Advanced Gas Turbine Technology for Power Generation*

*Note:* For comparison, the cost of electricity is also shown for a new 1,000 MW<sub>c</sub> coal-fired, steam-electric plant with flue gas desulphurisation.

*Source:* T.B. Johansson, H. Kelly, A.K.N Reddy and R.H. Williams, *Renewable Fuels and Electricity for a Growing World Economy: Defining and Achieving the Potential*" in T.B. Johansson, H. Kelly, A.K.N Reddy and R.H. Williams, *Renewable Energy: Sources for Fuels and Electricity* (Washington, DC: Island s, 1993), Ch.1, page 19.



*Figure 10. The Potential for Co-generation Using Sugar Cane Residues.*

*Note:* The left bar illustrates the most common existing situation at a sugar factory or a distillery during the milling season, in which residues are not used to generate power. The second bar illustrates a factory where steam-saving measures have been taken; these measures reduce the need for heat (steam) in the plant, which allows more of the sugar cane to be used in power generation. The remaining bars illustrate situations in which residues are utilised for power generation.

CEST -- Condensing-Extraction Steam Turbine

BIG/STIG -- Biomass Gasification, Steam Injected Gas Turbine

*Source:* R.H. Williams and E.D. Larson, "Advanced Gasification-Based Biomass Power Generation," in T.B. Johansson, H. Kelly, A.K.N Reddy, and R.H. Williams, *Renewable Energy: Sources for Fuels and Electricity* (Washington, DC: Island Press, 1993).

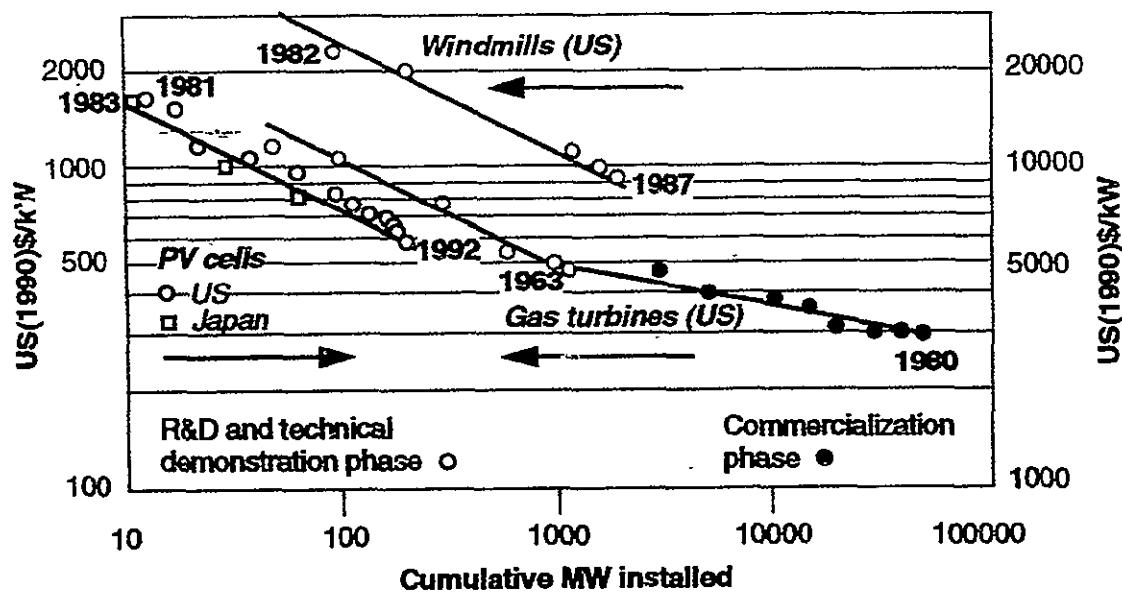
*Photovoltaic Power* In stand-alone applications for lighting, education, water pumping, and refrigeration purposes, remote from electrical grids, PV has been competitive for several years. In such applications, PV systems are often competitive with presently used kerosene, candles and dry-cell batteries, but typically there is no infrastructure to provide people with access to this technology.

The many available options for using renewable sources of energy that are either already cost-effective today, as evaluated through standard economic accounting, or have good prospects for becoming so, require targeted R&D efforts and stimulation of markets to support their introduction. What is needed is a) assistance in accelerating development of important new technologies and b) improving access to already affordable renewable energy sources for much larger fractions of the rural population.

An example in which assistance in accelerating development would make a difference is photovoltaic (PV) electricity. Over the long term, PV technology could provide a significant proportion of both decentralised and centralised power in developing countries. For PV cells (like for windmills and gas turbines) the cost per unit of output has declined steadily as volume has increased (Figure 11). According to some estimates, an investment of around US\$ 10 billion could create a market large enough to bring down the costs of grid-connected PV electricity to levels comparable to those of electricity from conventional sources.<sup>52</sup> Although sizeable, this amount is modest in comparison to global annual subsidies for conventional sources of energy. Recently published costs for planned grid-connected PV power projects in the US<sup>53</sup> suggests a much more rapid cost reduction path.<sup>53</sup>

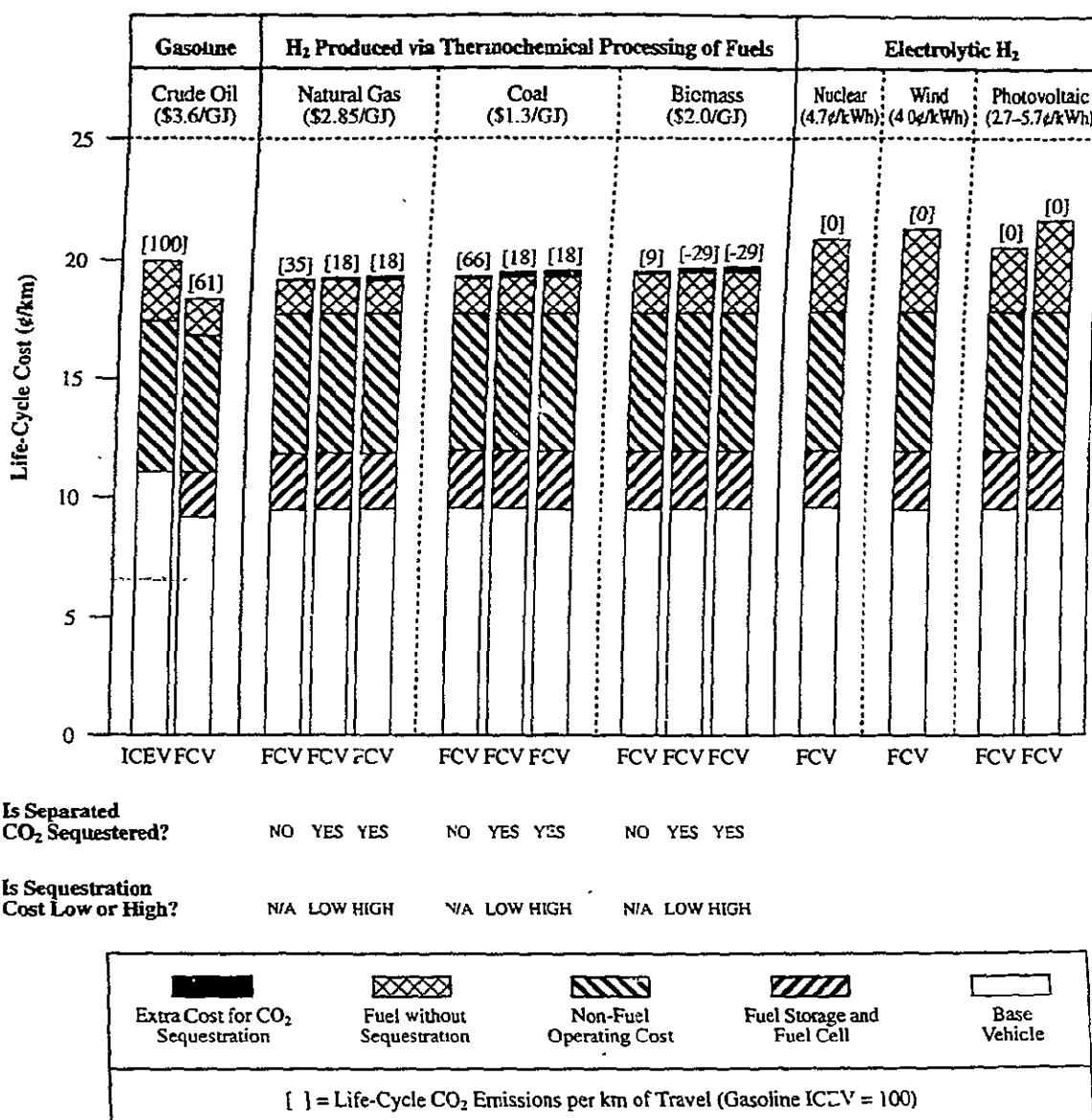
**Box 4. Decentralised Rural Electrification**

The recent successes of family or village-sized electricity projects for lighting, radio and TV, water pumping and other small uses, provide examples that markets exist and that consumers are capable and willing to pay for much improved levels of energy services. These successes have been achieved using PV, wind, and biomass technologies, which have offered people the possibility of investing in improved lighting, water pumping, and small productive uses, etc.<sup>54</sup> These markets are now largely unserved, and major opportunities exist to establish private sector activities to service these markets. The barriers that have to be penetrated for this to happen include capacity building (training), the establishment of credit facilities for families and villages, and a supportive legal framework.



*Figure 11. Cost Reductions Per Unit of Output versus Cumulative Installed Capacity for Photovoltaics, Wind, and Gas Turbines Over Time*

Source: World Energy Council (WEC) and International Institute for Applied Systems Analysis (IIASA), *Global Energy Perspectives to 2050 and Beyond* (1995). Numbers for 2020 and 2050 are from Scenario B, "Middle Course."



*Figure 12. Estimated Lifecycle Cost of Owning and Operating a Hydrogen Fuel-Cell-Powered Car (per kilometre of driving)*

*Note:* Total lifecycle costs and CO<sub>2</sub> emissions are shown for fuel-cell vehicles (FCVs) fuelled with H<sub>2</sub> derived from alternative primary energy sources, along with a comparison of lifecycle costs and emissions for gasoline-fuelled internal combustion engine vehicles and FCVs.

Source: R.T. Watson, et al Eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report, Working Group II*, (New York: Cambridge University Press, 1996). Chapter 19.

*Transportation*

The transportation sector, in the early stages of rapid expansion in many developing countries, is an excellent area for technological leapfrogging. Recent breakthroughs in fuel cell technology, for example, offer new possibilities. This technology, which combines hydrogen from on-board containers with oxygen from the air to generate electricity, makes electric vehicles possible. These vehicles generate their power source on board, have virtually no emissions and require no pollution-control technology. They can be easily and economically refueled, using fuels derived from natural gas, biomass, or coal.

Fuel-cell technology could become widely available for all modes of ground transportation, including trucks, trains, and buses. Bus fleets in many urban areas are growing rapidly. A technology demonstration project using fuel-cell buses could provide the needed impetus for a focused effort to move directly into a vehicle/fuel system much less cumbersome than the current one. Projected costs for fuel-cell-based transportation are comparable to projected costs of conventional petroleum-based transportation (Figure 12).

### **II.3 Technologies to Clean Up Conventional Fuels**

Even with increased end-use energy efficiency and expanded use of renewables, conventional supplies will still be required in many instances. Fossil fuels will continue to form the basis for much power generation and transportation, but the environmental impact of these uses of conventional fuels can be reduced.

The conventional fuel sector can be made more sustainable by switching to cleaner fuels, from coal to oil to natural gas, whenever possible. Natural gas typically contains no sulphur and thus contributes little to acidification and local air pollution. It contains nearly twice as much energy per unit carbon in the fuel as coal, thereby reducing CO<sub>2</sub> emissions. Many areas have large resources of natural gas. Low-capital-cost, highly efficient, advanced combined-cycle technology is reducing electricity costs considerably in areas where natural gas is becoming the preferred fuel. Natural gas is also partially replacing oil in the transportation sector.

Even when the dirtier fuels are used, they can be utilised in more efficient devices than just a few years ago. For example, coal can be gasified and the (cleaned) gas directed through a gas turbine or used in a combined-cycle plant, both of which represent dramatic efficiency improvements over traditional boiler technologies. Another approach is to decarbonise the fuels, i.e., to make hydrogen-rich fuels from fossil fuel feedstocks.<sup>55</sup> If conversion technologies, such as fuel cells, are available to

take advantage of the high value of these hydrogen-rich fuels, fossil fuel decarbonisation plus CO<sub>2</sub> storage would enable these fuels to be used in a more sustainable way. In fact, a fascinating vision of long-term future energy systems builds on decentralised use of fuel cells (fuelled with hydrogen-rich fuels) to provide power and heat for both buildings and transportation.<sup>56</sup>

#### **II.4 Can It Be Done?**

Is it technically possible to meet all of the environmental challenges associated with energy while increasing the supply of available energy and the living standard of billions of people? Can the new technologies make a difference? The answer clearly is “yes.”

To assess the potential impacts of alternative combinations of the individual energy supply options reviewed, IPCC constructed variants of a low CO<sub>2</sub>-emitting energy supply system (LESS) for the world, for the period to the year 2100. These LESS constructions are not forecasts, but rather are “thought experiments” or self-consistent representations of plausible energy futures for a world in which society accelerates the development and commercialisation of various combinations of the economically promising climate-friendly energy technologies that were assessed.

Focused attention was given to five LESS variants (see Figure 13). To help clarify the options, alternative versions of the LESS were constructed with features that make each option markedly different from the others. In the real world, there would be a mixing of some options, while other options might not be realised at all. The two LESS variants analysed in the greatest detail are taken to be the reference cases - a biomass-intensive (BI) variant and a nuclear intensive (NI) variant. The main features of the reference cases are highlighted in Box 5.

The BI and NI variants, a natural gas-intensive (NGI) variant, and a coal-intensive (CI) variant involve a high degree of emphasis on the efficient use of energy. Energy demand characteristics for the NGI and CI variants are the same as for the reference cases described in Box 5. A fifth High Demand (HD) variant has global energy demand growing more quickly.

Roles for fossil fuels in the LESS constructions are estimated on the basis of considerations of private costs, without considering carbon taxes. Particular attention is given to resource constraints on oil and natural gas, and to local environmental restrictions on the use of coal.

***Box 5 Highlights of the LESS Reference Cases (BI and NI variants)***

World population grows from 5.3 billion in 1990 to 9.5 billion by 2050 and 10.5 billion by 2100. GDP grows 6.9-fold by 2050 (5.3-fold and 13.6-fold in industrialised and developing countries, respectively) and 24.6-fold by 2100 (12.8-fold and 68.3-fold in industrialised and developing countries, respectively), relative to 1990. Because of emphasis on energy efficiency, primary energy consumption rises much more slowly than GDP. Global primary commercial energy use roughly doubles (see Figure 3), with no net change for industrialised countries but a 4.4-fold increase for developing countries, 1990-2100. The ongoing electrification of the global energy economy continues throughout the next century, with electricity generation increasing 1.8-fold in industrialised countries, 12.9-fold in developing countries, and 4.2-fold worldwide, 1990-2100.

Oil production declines in all regions, at a global average rate of 1.0%/year until 2100, when oil production is produced at 35% of the 1990 rate. Global natural gas production rises 84% by 2025, before beginning a decline at an average rate of 1.8%/year, 2025-2100; by 2100 natural gas is produced at 48% of the 1990 rate. Global coal production declines continually but in developing countries it first rises 70% by 2025 before beginning to decline. While the decline in oil and gas production is determined by resource constraints, declining coal production is due to competition from non-fossil energy.

Total fossil fuel use stays roughly constant, 1990-2025, but its share in global energy declines from 86% to 67% in this period and to 15% by 2100, as a result of a shift to renewables in the BI variant and to nuclear plus renewables in the NI variant (see Figure 3). The NI variant involves increasing nuclear capacity world-wide 10-fold by 2100, such that nuclear accounts for 46% of total electricity in 2100, while hydro, biomass, and intermittent renewables (wind, photovoltaic, and solar thermal electric power) account for 6%, 10%, and 34%, respectively. In the BI variant, nuclear provides 3% of electricity in 2100, while hydro, biomass, and intermittent renewables contribute 10%, 29% and 54%, respectively.

Biomass plays major roles (esp. as a feedstock for MeOH and H<sub>2</sub> production and power generation), accounting for 72 EJ or 15% of primary energy in 2025 (47% of biomass is for power generation), rising to 325 EJ or 46% of primary energy by 2100 (29% is for power generation) in the BI variant. In the NI variant, the contribution from biomass is 12% in 2025 (of which 35% is for power generation) and 38% in 2100 (of which 14% is for power generation).

MeOH and H<sub>2</sub> play growing roles as energy carriers in both the BI and NI variants. Their production accounts for 1/10 of primary energy in 2025, rising to 2/5 by 2100 (about the same as for electric power generation then). Natural gas provides nearly 3/5 of the energy from these energy carriers in 2025, but its share declines to 1/7 by 2100, while the biomass share increases from about 2/5 in 2025 to 2/3 by 2100. Electrolytic H<sub>2</sub> makes no contribution in 2025 but provides 1/8 of the energy from these energy carriers in 2050 and 1/5 in 2100.

Oil exports from the Middle East decline absolutely but grow as a percentage of global oil consumption, from about 1/5 in 1990, to more than 1/4 in 2025 and 1/3 in 2100. Total energy exports from the Middle East double, 1990-2050, before declining back to the 1990 level by the year 2100, as a result of growth in exports of natural gas and H<sub>2</sub> derived from both natural gas and solar electricity via electrolysis, which offset the decline in oil exports. Since H<sub>2</sub> is far more valuable than natural gas and oil, the monetary value of Middle East exports increases continually throughout the next century.

For the BI, NI, and CI variants, it is assumed that midrange estimates of remaining ultimately recoverable oil and natural gas resources are valid (11,300 EJ for oil and 12,500 EJ for natural gas) and that 80% of these resources are consumed by 2100. For the NGI and HD variants, the oil supply assumptions are the same, but it is assumed that a high estimate of remaining natural gas resources (17,400 EJ) proves to be valid and that 80% of these are consumed by 2100.

While coal is abundant and cheap, it is a dirty, difficult-to-use fuel. Where there are strict rules to ensure that coal is used in clean ways, coal will face stiff economic competition from many alternative energy sources. A key assumption is that by the time frame of interest (2025-2100), all regions of the world will have adopted environmental standards for using coals equivalent to the most stringent standards now in place in the industrialised world. A key additional assumption underlying the LESS reference cases is that if a non-fossil fuel alternative to coal is available at roughly the same cost for the final product (electricity or synthetic fuel) with these environmental standards, the alternative is selected.

The LESS variants differ in the treatments of both the electricity sector and the production of liquid and gaseous synthetic fuels. Most of the latter are used directly (not as fuel for power plants). Because the electric power sector accounted for only 1/4 of CO<sub>2</sub> emissions from the burning of fossil fuels in 1990, and because the technology assessment exercise identified fuels used directly as a much greater challenge in achieving deep reductions in emissions compared to the power sector, most of the variants differ from one another in the treatment of synthetic fuels.

The electricity supply schedule for the NI variant is for a world in which the current public opposition to nuclear power is overcome, to the extent that by the year 2100, world-wide nuclear capacity grows to 3,000 GW<sub>e</sub>. By 2100, nuclear and renewable supplies each account for about half of global electricity generation. For the other variants, it is assumed that the opposition to nuclear power is not overcome and that nuclear power's contribution to global energy does not increase. In light of the diversity of renewable electric options and their favourable prospective costs, the assessment found that a mix of renewable electric technologies could plausibly make up the difference in electricity needs if nuclear power is not resurrected, so that the CO<sub>2</sub> emissions from the power sector would be the same as for the NI variant. The electricity supply schedules for the NGI and CI variants are the same as for the BI variant.

Total global demand for liquid and gaseous fuels in the BI, NI, NGI, and CI variants, 1990-2100, amounts to 30,000 GJ (roughly half liquid and half gaseous fuel). Since this is far more than

what is likely to be available from oil and natural gas, synfuels play large roles in the LESS constructions. In the LESS constructions, synfuels production is dominated initially (through 2025) by methanol and later by hydrogen as well. Methanol and hydrogen are the energy carriers of choice for low-temperature fuel cells that could be used for transport and distributed combined heat and power applications, technologies that are assumed to come into wide use, beginning after the first decade of the next century.

In the BI and NI variants, these synfuels are produced partly from natural gas via steam reforming. It is assumed that hydrogen production from natural gas takes place near natural gas fields, with sequestering of the separated CO<sub>2</sub> in depleted natural gas reservoirs. The rest of these synfuels are produced from biomass via thermochemical gasification, with the biomass share growing over time (44% in 2025, 54% in 2050, 68% in 2100). In the NGI variant, it is assumed that the extra available natural gas supplies are used entirely to displace biomass in synfuels production, with sequestering of the separated CO<sub>2</sub> in the case of hydrogen production. The CI variant seeks to maximise the use of coal relative to biomass in synfuels production, subject to the constraint that the overall level of annual CO<sub>2</sub> emissions is the same as for the NGI variant. In this variant, some biomass-based synfuels production is used to "make room for coal" by requiring full sequestration of the separated CO<sub>2</sub> at the hydrogen and methanol production facilities for biomass as well as for coal.

For the HD variant, all the extra electricity supplies needed come from intermittent renewable sources, and all incremental requirements for fuel used directly are provided by hydrogen derived by thermochemical means from natural gas, biomass, and coal with sequestering of the CO<sub>2</sub> recovered at the fuel conversion plants. By 2050 and beyond, the HD variant uses as much primary biomass energy as in the BI variant and as much natural gas as in the NGI variant. The extent of sequestration is dictated by a requirement that annual CO<sub>2</sub> emissions not exceed those for the NGI variant.

Under all of the LESS variants, modernised biomass supplied from biomass energy plantations is a major source of energy. In industrial countries, biomass can be obtained by converting surplus agricultural land now subsidised to keep it in production (often not because the food is needed but to maintain a rural population) into biomass energy plantations. It is estimated that in Europe some 30-40 million hectares (Mha) could be used for this purpose; in the United States, 50 Mha. In developing countries, the first priority is food production; but land that is

available after food production is made more efficient can be used for bioenergy plantations. Such plantations can also restore degraded land. Some 2,000 Mha of land in tropical latitudes are classified as degraded, with few income-generating opportunities. Of this, some 600 Mha are considered suitable for reforestation.<sup>57</sup> With additional research and development, ways could be found to turn much of this land into bioenergy plantations.

Biomass energy plantations offer the greatest potential in Southern Africa and South America, where demand is projected to be particularly strong (Figures 15 and 16). These regions could become exporters of fuels derived from biomass (e.g., methanol). As already noted, such plantations are strong generators of rural employment.

Interregional trade in energy would grow in all the LESS constructions, during the next century. In addition to increased exports from the Middle East, regions such as Latin America and sub-Saharan Africa could become exporters of biomass-derived selfless.

CO<sub>2</sub> emissions from fossil fuel burning for the LESS constructions are presented in Figure 14, along with emissions from the IPCC's IS 92 scenarios shown for comparison. For all LESS variants emissions in 2025 are about the same as in 1990, and then fall to somewhat more than 4 GtC/year by 2050 and to about 2 GtC/year by 2100. Cumulative CO<sub>2</sub> emissions from fossil fuel burning, 1990-2100, for all the LESS constructions are in the range 450 to 475 GtC -- sharply less than the 1400 GtC from fossil fuel burning in the IS 92a scenario.

Costs for energy services in each LESS variant relative to costs for conventional energy depend on relative future energy prices, which are uncertain within a wide range, and on the performance and cost characteristics assumed for alternative technologies. However, within the wide range of future energy prices, one or more of the variants would plausibly be capable of providing the demanded energy services at estimated costs that are approximately the same as estimated future costs for current conventional energy. It is not possible to identify a least-cost future energy system for the longer term, as the relative costs of options depend on resource constraints and technological opportunities that are imperfectly known, and on actions by governments and the private sector.

These general findings relating to emissions reduction and costs are made possible largely as a result of two energy carrier trends that are implicit in all LESS constructions: a continuing electrification of the global energy economy (see Box 5) and a gradual shift to hydrogen as an energy carrier. Continuing electrification is important because of the diversity of electric technology options for reducing emissions, while the introduction of hydrogen as an energy carrier makes it possible to

achieve deep reductions in emissions for fuels used directly, especially in transportation. Both electricity and hydrogen can be produced with low emissions via a diversity of primary energy sources. The production of hydrogen via thermochemical means with sequestration of the separated CO<sub>2</sub> makes possible even a continued major role for coal in greenhouse-constrained world.

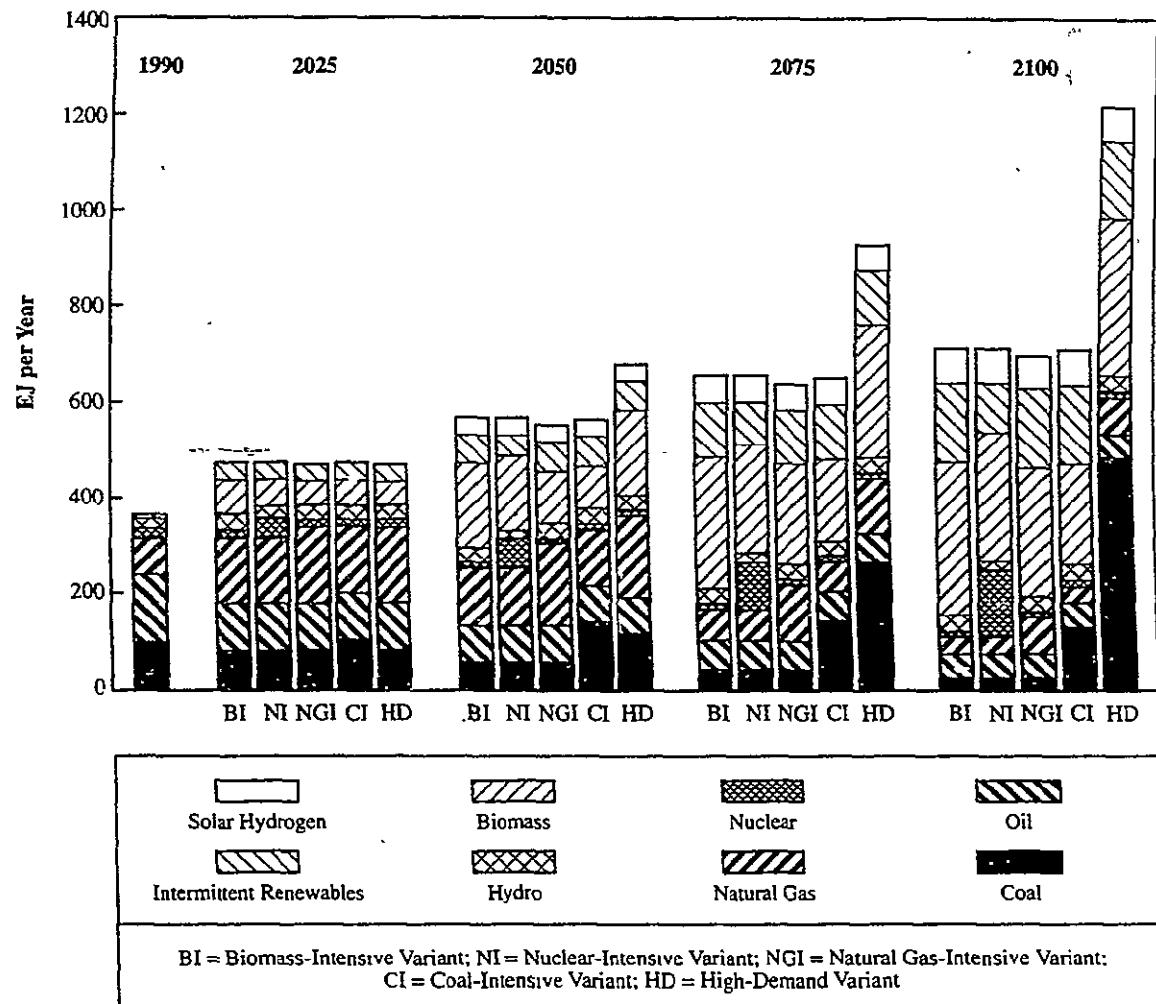
Sequestration requirements for the CO<sub>2</sub> separated from the produced energy carriers at the synfuel production facilities vary markedly from one LESS variant to another. In the BI and NI variants, which emphasise the use of biomass for synfuels production, cumulative sequestration requirements through the year 2100 are modest (less than 20 GtC), but are about 40 GtC for the NGI variant, 140 GtC for the CI variant, and 320 GtC for the HD variant. In principle, sequestration might be accomplished entirely in natural gas fields until the year 2100, even for the HD variant (Williams, 1996a; 1996). However, for the HD variant, the required sequestering rate by the year 2100 would be so high (about 12 GtC/year) that additional secure storage would be needed to be able to continue sequestering at high rates and, thus, maintaining low emissions at the high coal utilization rate of HD variant.

Major challenges must be effectively addressed in order to realise any one of the LESS variants, even if the performance and cost goals for the targeted energy technologies are fully realised. The public must be convinced that safety, waste disposal, and proliferation concerns can be effectively addressed if nuclear power is to play large roles in reducing greenhouse gas emissions. Potential land-use conflicts among the growing of energy crops, the growing of food crops, and preserving biological diversity must be effectively resolved in order for biomass to play large roles. Large roles for natural gas require that the optimistic projections of future natural gas supplies prove to be valid. And large roles for coal require the successful development of the theoretically appealing strategies identified for securely requesting the large quantities of CO<sub>2</sub> generated at synfuel plants. Not all of these challenges must be effectively addressed in order to evolve a global energy system characterised by low CO<sub>2</sub> emissions, however. Because of the large number of combinations of options, there is flexibility as to how the energy supply system could evolve, and paths to energy system development could be influenced by considerations other than climate change, including political, environmental, and socio-economic circumstances. However, higher energy demand levels reduce the flexibility for constructing supply-side combinations for deep reductions in emissions and increase overall energy system costs -- underscoring the importance of higher energy efficiency.

The literature provides strong support for the feasibility of achieving the performance and cost characteristics assumed for energy technologies in the LESS constructions, within the next one or two decades, though it is impossible to be certain until the research and development is complete, and the technologies have been tested in the market. Moreover, these performance and cost characteristics cannot be achieved without a strong and sustained investment in R&D. Many of the technologies being developed would need initial support to enter the market, and to reach sufficient volume to lower costs to become competitive.

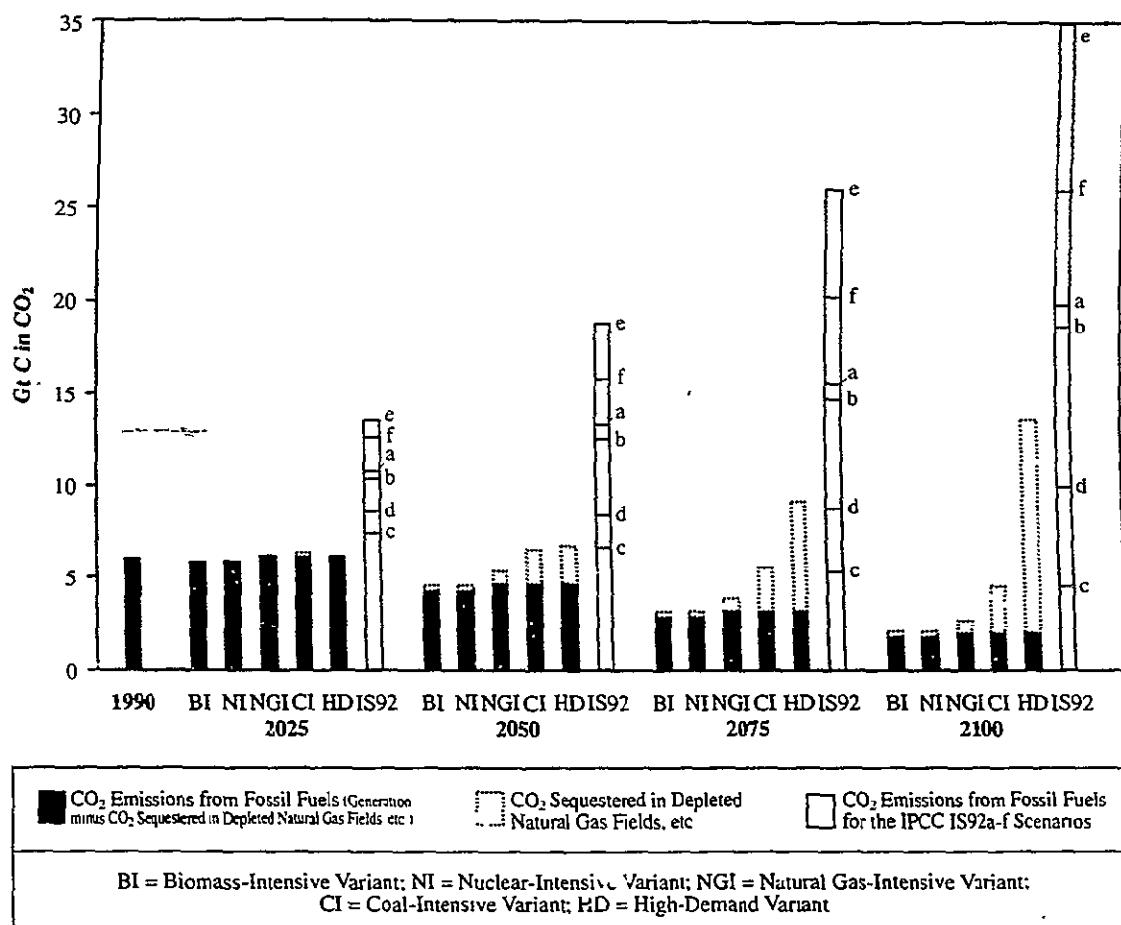
In addition to climate change concerns, there are several concerns of an immediate nature that would be addressed by the energy supply options discussed here (except carbon sequestering); for example, modern renewable sources of energy are often beneficial for local and regional environmental problems (e.g., urban air pollution, indoor air pollution, and acid rain) and for some technologies (especially biomass), rural income and employment generation, and land restoration and preservation. These energy supply options can be pursued to varying degrees within the limits of sustainable development criteria, which may however limit the exploitation of their full technical potential.

While it will require fundamental changes in energy systems development, the technologies clearly exist or could be further developed with additional investment in R&D to achieve the dramatic results of the LESS scenarios. What is needed is a commitment to realise the technologies' potential.



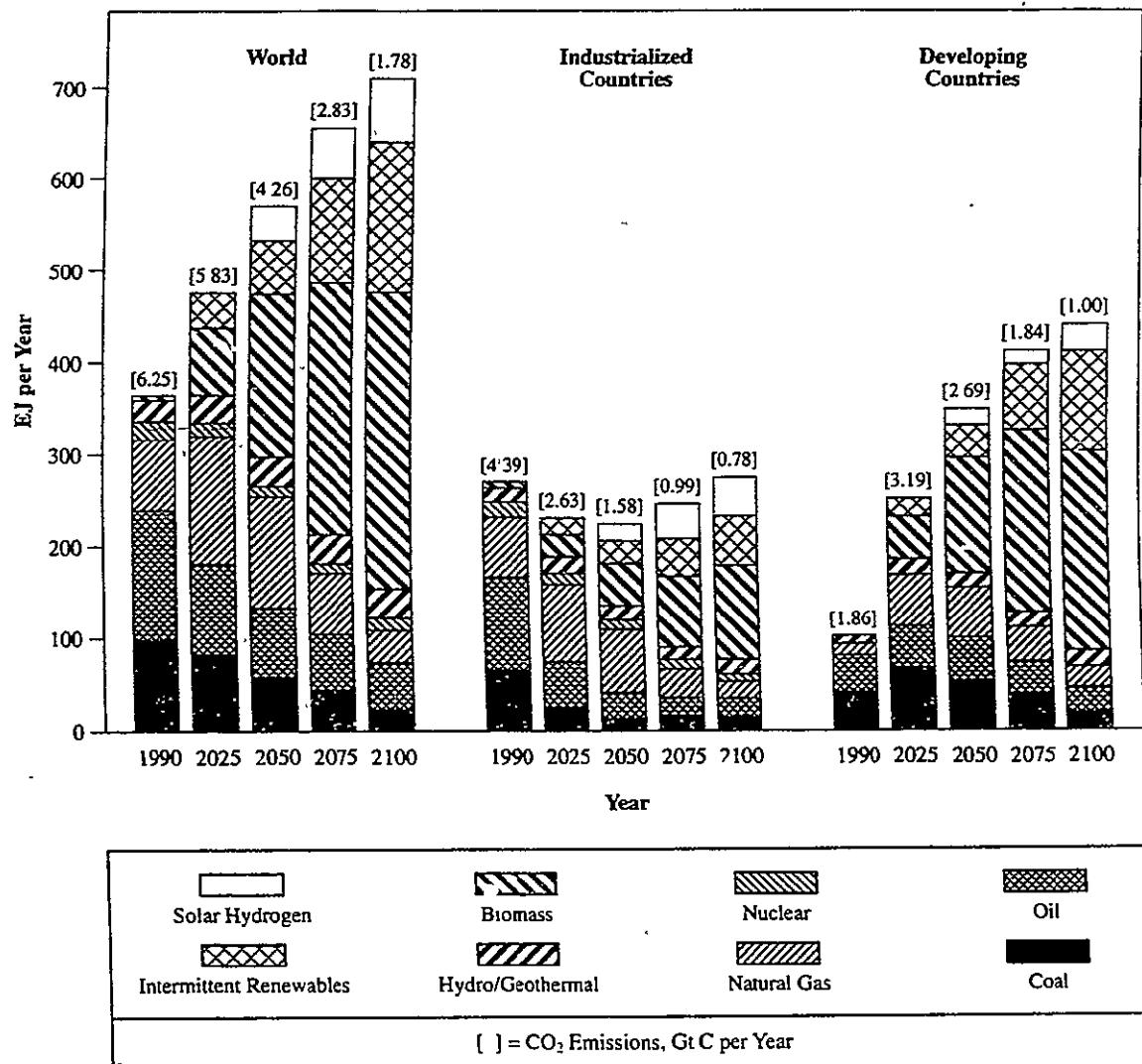
*Figure 13. Global Primary Energy Use for Alternative LESS Constructors*

Source: R.T. Watson, et al Eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report, Working Group II*, (New York: Cambridge University Press, 1996), H. Ishitani, T. B. Johansson, et.al. "Energy Supply Mitigation Options" Ch.19, p. 624.



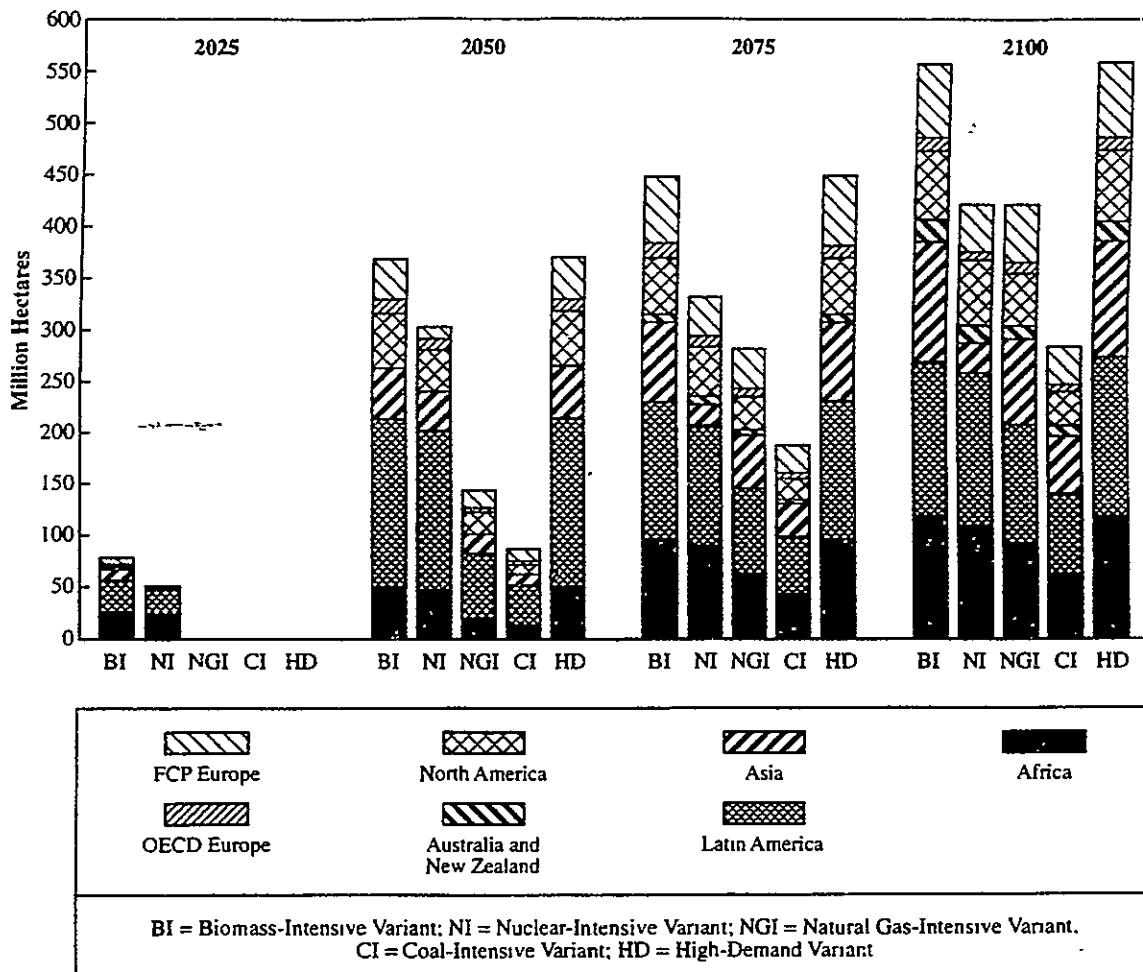
*Figure 14. Annual CO<sub>2</sub> Emissions from Fossil Fuels for Alternative LESS Constructors with Comparison to the IPCC IS92a-f Scenarios*

Source: R.T. Watson, et al Eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report, Working Group II*, (New York: Cambridge University Press, 1996), H. Ishitani, T. B. Johansson, et.al. "Energy Supply Mitigation Options" Ch.19, p. 625



**Figure 15. Primary Energy Use by Source for the Biomass-Intensive Variant of the LESS Constructions, World, Industrialised Countries, and Developing Countries**

Source: R.T. Watson, et al Eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report, Working Group II*, (New York: Cambridge University Press, 1996), H. Ishitani, T. B. Johansson, et.al. "Energy Supply Mitigation Options" Ch.19, p. 629



**Figure 16. Land Areas in Biomass Energy Plantations in Alternative LESS Constructors**

Source: R.T. Watson, et al Eds., *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change, IPCC Second Assessment Report, Working Group II*, (New York: Cambridge University Press, 1996), H. Ishitani, T. B. Johansson, et.al. "Energy Supply Mitigation Options" Ch.19, p. 627.

### **III. THE UNDP INITIATIVE FOR SUSTAINABLE ENERGY**

If today's developing countries are to achieve people-centred economic growth, guided by the paradigm of sustainable socio-economic development, they must undertake a new energy path that uses new technologies and approaches. They must transform old patterns of behaviour to become compatible with the challenge of sustainable development.

This transformation must involve moving away from *energy consumption* as the measure of development -- an approach that implies that the task of energy planning is to make projections of energy consumption into the future and to design supply mixes to meet these projected energy requirements. What is needed instead is a new approach to energy in which *the level of energy services* is the indicator of development. It is the level of energy services, rather than simply the amount of energy consumed, that determines the satisfaction of basic human needs, the quality of life, and the standard of living. Energy, rather than acting as a barrier to sustainable development, can contribute to success in those areas critical to sustainable human development, including:

- \* *urban development* (by providing low-cost intra-urban public transportation and community waste management programs -- activities which simultaneously generate jobs and improve the physical environment);
- \* *rural development* (by providing renewable forms of energy that can increase the amount of daytime available for economic activity and employment generation);
- \* *improved quality of life for women and children* (particularly the poor in both rural and urban areas, by reducing, *inter alia*, the time spent gathering firewood and breathing fire exhausts in an enclosed area);
- \* *agriculture and forestry* (through using biomass waste streams and biomass plantations that in turn help restore degraded land while providing employment and sustainable energy supplies), and
- \* *industrial development* (by introducing advanced technologies that reduce energy requirements in both the basic materials industries and the manufacturing industry, as well as by enabling the production of more energy-efficient products).

A sustainable energy strategy -- combined with sustainable strategies in these areas -- can contribute substantially to sustainable human development.

The UNDP Initiative for Sustainable Energy (UNISE) is designed to move the world toward a more sustainable energy strategy and ultimately a more sustainable development path.<sup>58</sup> Based on the principle of learning-by-doing, and maximising the use of indigenous expertise and institutions, UNDP can be instrumental in:

- \* promoting energy efficiency in new plant and equipment; and
- \* encouraging the development and dissemination of renewable energy technologies.

The activities to promote sustainable energy strategies include:

- \* mobilising support for indigenous capacity building, so that countries can identify and make use of new approaches and technological opportunities as well as train entrepreneurs and implement new financing/credit modes;
- \* encouraging countries to create a supportive legal, institutional, and regulatory climate for sustainable energy development, including an investment climate that will attract private capital;
- \* contributing to a leapfrogging strategy through innovative demonstration projects and through promoting the rapid development and dissemination of key technologies for sustainable energy development;
- \* supporting the formulation and implementation of national energy action programmes linking measures to goals in areas affected by energy system developments;

The challenges of achieving a sustainable energy strategy are enormous. However, UNDP is only one of the actors and can only play a limited role. However, UNDP is well positioned to undertake leadership in moving toward sustainable energy development. Its experience in building indigenous capacity, combined with a certain degree of convening power, respectability, and credibility, and its decentralised structure, create the basis to take a lead role in this area. In developing and carrying out UNISE, UNDP should work with other agencies, non-governmental organisations, the private sector, and donor governments toward the common goal of sustainable development.

### **III.1 Building Indigenous Capacity**

An essential requirement for designing and implementing a sustainable energy strategy is sufficient human and institutional capacity -- within programme countries, within UNDP, among non-governmental organisations (NGOs), in the private sector, in academia, and in professional schools.

Human resources are essential to a country's capacity to carry out work in any specific substantive area. In order to develop a sustainable energy strategy, a country needs its own cadre of professionals who understand both the elements of sustainable energy and that country's unique situation. Although outside expertise can supplement a country's expertise, the use of foreign consultants is only a stop-gap measure. To develop and implement a sustainable energy strategy on a continuing basis, each country must have a group of trained professionals to meet the challenges of policy design, development, and implementation.

Professionals and policymakers need to be made aware of, and educated and trained to deal with, the technical, legal, regulatory, institutional, and other issues associated with the challenge of sustainable energy development. Most energy planners working with utilities, government ministries, and agencies have focused on supply-side planning for their entire careers. The need for sustainable energy now challenges them fundamentally to widen their approach, learning to consider energy not so much in terms of increasing total supplies, but in terms of providing energy services for specific needs. With other professionals, energy planners need to move toward an interdisciplinary approach. Incorporating energy into sustainable human development projects needs the input of many specialities.

In addition, developing countries need to strengthen their institutional capacities to creatively address energy issues. Ministries, NGOs, universities, the private sector, and donors all have a role to play. However, utilities and energy ministries typically focus their attention on supply-side planning; university departments often remain within the bounds of relatively narrowly defined disciplines; and NGOs, to the extent that they even exist, do not always have personnel with the technical skills to contribute to energy debates. Increasing the capacities of such institutions to support sustainable energy would enable societies to move down a new energy path.

Capacity building has a number of purposes:

*Within government*, the purpose of capacity building is a) to ensure that all sectors of government (finance, planning, line ministries, etc.) are sufficiently informed, trained, and convinced to take proper decisions on energy strategy; b) to give energy strategy its proper place in national

policy for development; c) to prepare the country's institutions for, and involve them in, taking proper decisions concerning the generation and use of energy; d) to make government responsive to the needs of all society; and e) to encourage sectors of society to participate in decision making.

*Within society*, the purpose of capacity building is a) to provide information on the factors that influence how energy-related decisions are made; b) to ensure that the benefits from energy policy are distributed equitably; and c) to give NGOs and other representatives opportunity to participate in decision making.

Finally, *within the energy sector*, the purpose of capacity building is a) to ensure that basic information is available; b) to help energy professionals join in dialogue with policymakers; c) to transfer modern technical knowledge on energy issues; and d) to make institutions and businesses more efficient.

*A variety of methods can contribute toward capacity building.*

*Policy review.* Reform of legislation and regulations. Round-tables of senior policy-makers. Workshops for officials. South-South exchanges of experience and information. Information networking and connection to international sources of information. Training. Workshops with NGOs.

*Participatory exercises.* NGO strengthening. Assistance in formulating and implementing local initiatives. Improved school and university curricula.

*National surveys of energy demand and supply* involving technicians in policy dialogue.

*Education and training.* Involvement of universities in energy analysis. University courses in energy issues. Technical training for employees. Business, finance, marketing skills, project management, and legal skills related to energy development.

UNDP should utilise its extensive experience in working with people and institutions from developing countries in numerous sectors to strengthen professional capacities. For example, UNDP should sponsor workshops on sustainable energy to simultaneously strengthen both host-country and UNDP capacities. These workshops should provide training in the perspectives, techniques, and tools of energy planning for sustainable development, as well as information about key technologies. Furthermore analytical capacity could be built up (e.g., UNDP could support Integrated Resource Planning groups at universities and research institutions in a country). Such initiatives could be combined with in-country reviews of energy policies, thereby increasing both the intensity and the content of the local energy policy dialogue.

### **III.2 Improving the Policy Environment**

In many countries, the potential for implementing sustainable energy programmes is limited severely by existing laws, regulations, and incentives. For example, energy prices do not reflect the full costs of energy, and utilities frequently are not able to buy power from co-generating producers and may have no incentives or capacity to encourage consumers to reduce consumption.

Energy prices are flawed in two ways. First, government subsidies for energy in developing countries were over US\$ 50 billion in 1992, more than total official development assistance to these same countries after accounting for debt service payments.<sup>59</sup> Policies should be designed to encourage energy prices that reflect the true and full costs of energy. Of course, price structures need to be changed gradually, with explicit attention to the effects of such changes on the poor. Second, the costs of environmental degradation are not reflected in the price consumers pay. These costs come, for example, as air pollution affecting human health, land degradation, acidification of soils and waters, and climate change.

With total annual energy investment needs in developing countries in the order of US\$ 100 - US\$200 billion dollars per year,<sup>60</sup> government investment, public sector loans, and concessionary financing will not suffice. The capital market must be involved. In many countries, this requires creating a policy environment that will attract capital to sustainable energy investments. This may involve forming capital markets and building investor confidence in order to attract external finance, joint ventures, and equity participation by foreign interests. This will require, *inter alia*, clear ownership rules, litigation procedures, and the introduction of transparent accounting and auditing. Such conditions have been or are being created in many countries.

Privatising energy industries is now widely recommended to increase economic efficiency in the energy sector, especially the power sector, often dominated by large parastatal institutions. Turning these institutions into corporations and requiring them to work in a regulated, competitive environment could considerably increase the energy system's economic efficiency. At the same time, there must be room for independent power producers, access to the grid for interested parties, as well as rules and procedures that require least-cost solutions on a national basis.

In addition to promoting economic efficiency, the legislative and regulatory environment must also promote such goals as sustainability and meeting the needs of disadvantaged groups. Improved energy efficiency and increased utilisation of renewable sources of energy are strategies for realising these goals and should be promoted by appropriate laws, regulations, and policies. For

example, for development to take place in a significant way, large capital investment is needed in all sectors -- levels of capital that can only be accessed through the private sector. This means that creating the terms and conditions that will attract private capital to sustainable development is an important policy concern. At the same time, the institutional and regulatory setting must ensure that projects meet social as well as financial objectives. Examples of activities and projects that meet both efficiency and social goals include *temporary subsidies, decentralised rural electrification, and the promotion of energy service companies*.

Although permanent subsidies to conventional sources of energy promote inefficiency, *temporary subsidies* have proven very effective in introducing new, better-performing technologies into the marketplace.

*Decentralised rural electrification (DRE)* is essential to meet the basic power needs of the more than two billion rural people who currently have no access to electricity. Extending the electric grid to rural areas in developing countries at the current rate would take at least 20 to 30 years; in the least developed countries, it could take more than a century.<sup>61</sup> Local mini-grids, on the other hand, could introduce electrification to rural areas more quickly and more economically. Such grids can use diesel generators fuelled with biogas or producer gas, or they can use small hydro-, wind, or photovoltaic plants. UNISE can help design policy instruments that will give producers and consumers of such DRE technologies (even those that are perceived as expensive, such as photovoltaic power) access to financial markets. The key feature is an arrangement that allows the high initial cost of the technology to be converted to an operating cost, thereby enabling households to get higher levels of energy services without increasing monthly expenditures; such an arrangement allows existing payment levels to cover both capital and operating costs of the new technologies.

Another option is to encourage *energy service companies (ESCOs)*. Energy service companies are businesses that invest in retrofitting and other efficiency measures for commercial and residential buildings. The ESCO enters into a contract with the owner of a building to undertake steps to reduce energy use. Customers typically continue to pay their old utility rates until the investment costs of the improvements are paid for. Thereafter, the ESCO passes the savings on to customers in the form of lower energy bills. Thus, the reduced energy costs of the customers provide the initial cash needed by the ESCO for its operation. Customers are compensated by lower energy costs once the investment is paid for.

Difficulties in measuring and verifying the results achieved have made it difficult to interest investors; growth in the ESCO industry has been slow. Now, however, a new protocol to measure and ensure savings from efficiency investments has potential world-wide application.<sup>62</sup>

UNDP should assist governments in creating a supportive policy environment for sustainable energy initiatives. This requires working with ministries, agencies, utilities, universities, research organisations, NGOs, and the private sector, in order to help analyse opportunities and make relevant information accessible. UNDP should also help broker financing packages with various multilateral, bilateral, and private funding sources by acting as a catalyst, not as funder.

Catalysing, supporting, and enabling countries to pursue more enlightened energy policies is consistent with UNDP's perceived strengths and its current operational practices. UNDP should utilise this experience to support countries that want to strengthen their legal, regulatory, and institutional frameworks to promote a sustainable energy strategy.

*Micro-credit for Energy* is a promising new approach evolving in the fight against poverty. The poor are seen not as beneficiaries of government largess but as clients with assets whose preferences and needs must be respected. Micro-financing has demonstrated success not only in providing access to energy services for poor households but also in generating income and alternative economic activities. An important UNISE principle is to facilitate access to affordable energy technologies for which people are willing to pay full cost. UNDP can help break the barriers to accessing such technologies by creating the financial and other incentives that will spark private investment. Some of that investment can come from the poor themselves..

The poor currently spend approximately 10-20 percent of disposable income to obtain the relatively inefficient energy services they now have. This expenditure may be to procure kerosene, candles, fuelwood, or other forms of fuel for combustion, or may represent the cost of electricity to households on grid. Expenditure on energy represents forgone consumption or expenditure on other items needed by poor households. But the poor are often good savers. While many poor households cannot afford one-off capital investments to introduce alternative energy-generating units or, at the village level, to install mini-grids, the pro-rated expenditures on these energy services would in many cases be less than the cost of the conventional energy currently being consumed. As such, poor households represent a large market from which private sector investors and banking institutions can draw capital in order to disseminate energy services through micro-credit investment financing.

These new sources of capital could be mobilised to form an investment pool that could be leveraged to provide small-scale renewable energy technologies on a widespread basis. What is needed is a new concept of risk and return, in which public sector capital becomes subject to more commercial discipline than in the past, and private sector capital accepts longer lead times for return on capital. With such help from the public and private sectors, the investment money from the poor themselves can help develop and disseminate the technologies (such as solar panels) that can significantly improve the lives and well-being of the poor.

UNDP's role in facilitating micro-credit schemes lies not in the management of projects that operate the schemes, but in the up front financing of market studies and development of business plans to assist private sector interests in establishing and operating the new credit systems. Efforts to address uncertainty provide the necessary interface between poor communities, energy services, and private capital. Through such efforts, UNDP will contribute to capacity building while facilitating the delivery of energy services to the poor. Financing mechanisms that make sustainable energy technologies available through the market require an element of sound and equitable risk sharing.

### **III.3 "Leapfrogging" to New Technologies and Approaches**

Developing countries have the possibility to "leapfrog" past the methods used by today's industrialised countries, moving quickly and directly to the highest performance technologies. In many cases, the emerging new technologies will require some adaptations to the specific conditions of developing countries. Because they were often developed for use in industrialised countries -- where labour is expensive and capital relatively cheap -- new technologies tend to be labour-saving and capital-intensive. Developing countries -- where capital is expensive and labour relatively cheap -- have different technological requirements. Despite the need for adaptation, new technologies offer the best hope for today's developing countries to move toward sustainable energy development.

The crucial importance of technological leapfrogging in the energy sector is not well understood, especially in developing countries, where energy planners may be unwilling to take risks in exchange for what appear to be only medium-term payoffs. They may be cautious because of previous disappointments in new-technology transfers, or simply because of the large size of many conventional energy projects. The major lending agencies reinforce this caution when they insist that a particular technology or approach should have a proven track record in industrialised countries before providing financing.

Fortunately, not all technological leapfrogging involves high-risk innovation. This is especially true for situations where the most efficient available technologies are used for new investments in a developing country. In other cases, leapfrogging may involve introducing technologies into developing countries that have not yet been used elsewhere or that are just being introduced in other markets. Careful assessment of the risks attached to a specific leapfrog project compared with the potential benefits to the industry and to society can help make a more informed decision.

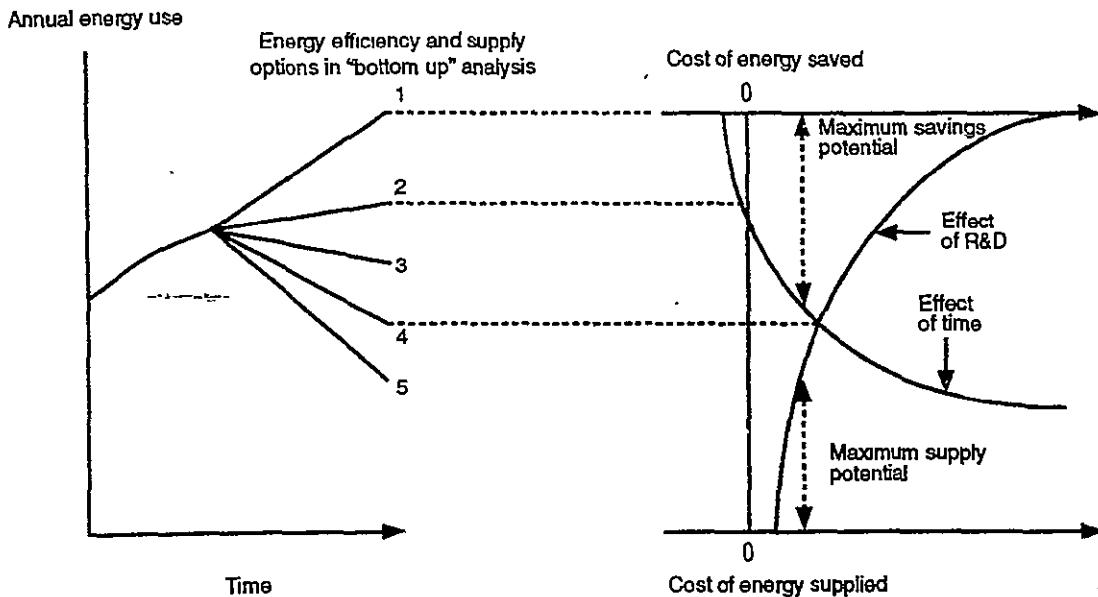
Technology procurement has proven an effective policy tool to bring better performing technologies to the market<sup>63</sup>. Market acceptance has been further enhanced by cooperative procurement.<sup>64</sup> These approaches have so far been mostly used for energy-efficient appliances.

UNDP can contribute to leapfrogging in two ways. First, UNDP can identify and help implement a series of innovative demonstration projects in key technology areas. It can promote cooperative procurement processes in order to bring new, more energy-efficient products, with more advanced performance criteria, into the marketplace. Selectees in these procurement processes may build the products/facilities in co-operation with local partners, under appropriate government guarantees and legally protected intellectual ownership. In addition to private sector investment, funding can come from multilateral and bilateral sources, including the Global Environment Facility.

Second, UNDP can work toward a global program for accelerated development of important new technologies, including decentralised PV, wind, biomass, and electricity generation, and other renewable energy technologies.

#### **III.4 National Energy Action Programmes**

Sustainable energy development aims at meeting today's energy needs without compromising the needs of future generations. Fundamental to this concept is the idea that energy is an intermediate good, useful not as an end in itself, but as a means to an end. A sustainable energy strategy, therefore, would propose to replace present energy-supply systems with improved technological systems that are more environmentally friendly and able to match energy supply to the work performed.



*Figure 17. The Relationship Between Bottom-Up Energy Scenarios and Marginal Costs*

Source: T.B. Johansson and J. N. Swisher, "Perspectives on Bottom-Up Analysis of Costs of Carbon Dioxide Emissions Reductions," OECD/IEA International Conference Proceedings, *The Economics of Climate Change* (1994).

**Box 6. The Relationship Between Bottom-Up Energy Scenarios and Marginal Costs**

The left side of Figure 17 illustrates the development of energy use up to the base year of the study, and shows five scenarios with different levels of energy demand for the end year of the study. For all scenarios, the assumed growth in population and economy is the same. Note that all values apply to a given year.

Scenario one reflects the growth in energy services provided, as if the average energy intensity for each activity would not change after the base year. This scenario is often referred to as the "frozen efficiency" scenario. The other scenarios describe various levels of improved energy efficiency, meeting the same level of energy-service demand, but with different combinations of energy efficiency and energy supply.

In scenario two, the energy intensity is reduced, for example, to the level of the average of new equipment in the base year. It is a "frozen new model" scenario, where the marginal cost of efficiency improvements is still zero or negative. Improved energy efficiency has reduced the need for energy supplies, and the marginal energy-supply cost is reduced. This scenario reflects existing trends in energy-efficiency improvement; it is a reference scenario reflecting what can be expected with no policy change.

In scenario three, the mean energy efficiency in the end year may be assumed, for example, to reach the level of the most energy efficient technology on the market in the base year.

Scenario four can be described as the least-cost scenario because increasing supply would cost more than increasing savings through energy efficiency, and vice-versa.

Scenario five illustrates the case where ongoing research and development makes more energy-efficient technologies available, and these penetrate the market significantly enough to bring the stock average energy intensity below that indicated in scenario four.

It follows from the process of creating possible future scenarios that the one with the lowest cost, broadly defined, is an *outcome* of the analysis. This simple point is very important, because it means that it is not *assumed* that one scenario, such as the one most like the status quo, is the best. The cost optima are often rather broad, indicating that a range of options are similar in cost. Thus decisions could be made on the basis of other criteria, such as environmental quality or social equity.

The costs and amounts of energy supplies and efficiency potential can change over time, because a larger fraction of the stock will be replaced in a later year, thus offering more opportunities to introduce new technology. Additionally, ongoing R and D will bring more advanced products to the market.

The right side of Figure 17 illustrates the energy efficiency supply curve. This is constructed from the level of base-year frozen efficiencies. It starts with negative cost measures, that is, measures that will reduce the costs of obtaining the energy services. The curve may be thought of as a step curve with a large number of steps, each corresponding to a certain technical measure. Summing each of the measures, which have different costs in each application, causing the steps to overlap, results in a smooth energy-efficiency "supply curve."

The bottom part of the right side of Figure 17 illustrates the supply technologies and their costs. These technologies can, in principle, supply all the energy-service needs of the reference scenario or even the "frozen efficiency" scenario, although at a higher cost than necessary. The least expensive energy supply comes with a net positive cost, as shown, and more expensive options are included in order of cost.

The most important assumptions in bottom-up models are the costs, energy intensities, and lifetimes of technologies currently in use and their alternatives; fuel and electricity costs; and the potential rates and limits of alternative technology penetration. The models are designed to identify the opportunities presented by a changeable world. Energy-economy interactions are not only changing but *changeable* in this modelling methodology.

In addition to identifying technological potentials, bottom-up analysis describes the market limitations and barriers, such as equipment turnover rates and capital requirements, which constrain input parameters, such as rates of energy-efficiency implementation. Without policy changes, market barriers will hinder the achievement of identified potentials. For this reason, all measures (negative-, zero- and positive-cost) are included as potentials in the analysis. The alternative scenarios are generated and perceived as achievable under the presumption that policies are designed to remove the barriers.

To implement such a strategy, countries will require co-ordinated national energy action programmes. These action programmes will focus on the tasks for which energy is required, not the quantity of energy produced or supplied. Such action programmes should aim to 1) improve the end-use efficiency and cost-effectiveness of both energy and materials, 2) increase the use of renewable energy sources, 3) use conventional fuels in cleaner ways, and 4) extend energy services (based on electricity and modernised fuels) to the developing-country majority that now have no access.

*Integrated resource Planning* is a powerful analytic tool that can aid in the formulation of national energy action programs. Conceptually, IPP is straightforward. Planners rank by cost all the various energy-supply and energy-use technologies that might be used to provide an energy service, identifying the order that the options would be chosen to achieve the lowest-cost options to implement. Thus various electricity supply technologies such as conventional coal plants, wind generators, hydro plants, and steam-injected gas turbines are compared with each other and with end-use technologies such as compact fluorescent lights and increased insulation in buildings to reduce air conditioning loads. Of all the different possibilities, the lowest-cost options are chosen first for investment.<sup>65</sup> IRP can help set priorities and lead to least-cost mixes of efficiency improvements, decentralised renewables, and cleaner centralised sources. IRP is used in electricity planning to evaluate which demand- and supply-side initiatives are most cost-effective and therefore deserve to be undertaken. It involves comparing the associated costs (including environmental impacts) of all possible approaches to improved energy services, i.e., both increasing supply and improving efficiency. Thus the potential of both demand- and supply-side alternatives are assessed to find the true least-cost options.

IRP can help improve energy utilisation. However, utilities are not likely to use IRP without a rational energy pricing system or regulatory incentives. The experience of the United States, where changes in the rate-making formula led to increased use of integrated resource planning, illustrates the importance of a conducive regulatory climate (Figure 17 and Box 6).

UNDP should support the development of national energy action programmes that provide an integrated understanding linking quantitative national goals to a set of energy measures that can reach the goals. National energy action programmes should include emphases on capacity building, policy formulation, and technological leapfrogging. They should especially utilise the powerful analytic tool of integrated resource planning.

#### ***IV. IMPLEMENTING UNISE: FROM APPROACH TO ACTION***

Making energy an instrument of sustainable development will require the participation of many sectors, institutions, and individuals in society. If the changes in global society called for by the international community in Agenda 21 are to be realised, sustainable energy strategies must become the mainstream approach to new investments in energy.

Investment needs in energy supply and demand in developing countries are in the order of US\$ 100-US\$200 billion per year, with most of this coming from capital markets and Government funding of nationally owned energy institutions. Development assistance financing for energy is less than US\$11 billion (net of debt financing) per year with most of this coming from the World Bank and other multilateral development banks<sup>66</sup>.

Currently, the majority of investment, which comes mostly from private and international capital markets, goes to the expansion of conventional energy supply. Changing the direction of energy system development will require fundamental changes in where investments are made and in how the private sector and financial markets operate with respect to energy. Used wisely, development assistance funds -- though only a small proportion of the total -- can 1) help advance understanding of how a more sustainable system of energy development can be achieved and how perceived risks associated with the provision of energy services to the poor can be overcome; 2) demonstrate through carefully selected projects the financial and environmental effectiveness of the new technologies and approaches; and 3) leverage additional resources for sustainable energy.

UNDP has an opportunity to undertake a new approach to sustainable energy issues. As discussed above, a sustainable energy strategy can be a crucial instrument in meeting UNDP's goal of promoting sustainable human development. Energy is integrally linked with UNDP's top priority -- poverty elimination -- as well as its other concerns of creating jobs, advancing the health and well-being of women, and regenerating the environment. Energy affects many aspects of sustainable development -- economic and social development and growth; the local, national, regional, and global environment; the global climate; a range of social concerns, including poverty, population, health, and gender-related issues; the balance of payments; and prospects for peace. The need for energy services will continue to grow, driven both by growth in populations and the aspirations of people around the world for a better life. Whether those energy services can be provided and contribute to

achieving sustainable development depends very much on the choices the international community makes in the near term. UNDP can play a role in moving in that direction.

UNDP has a substantial history of technical assistance related to energy. Over the last two decades, it has provided more than US\$ 400 million for over 900 projects in the developing world. Most of this funding was for energy planning and conventional sources of energy (oil, gas, and coal), although UNDP also funded electric power, renewable energy, nuclear energy, and energy efficiency projects. UNDP's future work should build on this experience (Appendix A), as well as on that of other agencies and partners.

Despite its active role in the energy sector, UNDP has not had an overall approach to energy issues and funding. Rather, it has primarily responded to country requests. The UNDP Initiative for Sustainable Energy addresses this lack through a comprehensive approach that not only focuses UNDP energy activities, but also helps to advance UNDP's goals and priorities, as determined by the Executive Board in June 1994 (Box 1, p.4).

#### **IV.1 UNISE and the Successor Programming Arrangements**

UNISE is initiated just as UNDP is beginning its new programming arrangement, moving from its traditional five-year fixed programming structure to a three-year, more flexible cycle. The rationale for the new programming framework is to make possible "keenly focused, high-impact and high-leverage programmes that support national efforts toward poverty elimination and sustainable human development."<sup>67</sup> The urgent need for higher levels of energy services and the possibilities offered by the emerging new technologies make energy a prime candidate for such programmes. As detailed in Chapter II, many technologies that could efficiently and cost-effectively provide higher levels of energy services either already exist or are in advanced stages of development. What they need is an interested party to facilitate broad recognition of their potential and to mobilise funding and political support from a variety of sources.

The timing is right. With the successor programming arrangements, UNDP has the flexibility and capacity to take advantage of technological and political opportunities, as well as to respond to country priorities. The new arrangements eliminate the IPF (Indicative Planning Figure) entitlement concept, replacing it with TRAC (Target for Resource Assignment from the Core) which comes in two forms: TRAC I which is directly managed at the country level, and TRAC II which is centrally allocated to promote UNDP thematic priorities. To obtain TRAC funding, projects and

programmes must promote sustainable human development and meet the following criteria. They must: a) contribute to national priorities, b) strengthen national capacity, c) be consistent with UNDP's priority areas, d) leverage a broader development impact (e.g., eliminate bottlenecks or serve as a model to be replicated elsewhere in the country), and e) have the potential to attract and mobilise additional public and/or private resources.<sup>68</sup> Energy projects that promote sustainable human development meet all of these criteria. The introduction of the successor arrangements with enhanced focus on sustainable human development will imply that energy sector activities which reflect the UNISE approach will be highly relevant for the allocations of TRAC I and TRAC II programmable resources.

*National Priorities.* Expanding energy services to meet the needs of their growing populations and the needs of their productive and service sectors is an urgent priority in all developing countries. In the past, the policy focus has often been to increase energy supply; as this paper demonstrates, however, the real goal should be to increase the level of energy services in a sustainable and cost-effective way. The kinds of sustainable energy strategies inherent in UNISE can contribute to meeting national goals of socio-economic development.

*National Capacity.* In every sector, developing countries are seeking to increase individual and institutional decision-making capacities. Because energy is integrally related to so many other development sectors, strengthened capacity in that sector will impact on a variety of public and private institutions -- including government ministries, non-governmental organisations, universities, enterprises and local government officials.

*UNDP Priority Areas.* As argued repeatedly in this paper, sustainable energy activities not only are consistent with, but actually promote, sustainable development objectives in UNDP's priority areas of poverty eradication, employment creation, advancement of the health and well-being of women, and protection and regeneration of the environment.

*Programme Leverage.* A key aspect of UNISE is to promote projects that will advance the development and use of the many new technologies available by eliminating the information, political, financial, and other barriers that keep their potential from being realised. These demonstration projects can then be replicated in other parts of the country as well as in other contexts. The most important leveraging function will occur vis-à-vis the private sector and financial markets: by advancing innovative technologies and concepts and demonstrating their viability, UNISE will encourage private interests to become engaged in their continued dissemination.

*Resource Mobilisation.* UNDP's role in energy, as in other areas, is not to provide all the needed funds, but to use its influence and its limited funds to steer global energy choices toward a more sustainable path. Through UNISE, UNDP will form partnerships with actors in the public and private sectors to leverage and access other, larger sources of finance, including private sector financing. By using its own limited funds to develop and highlight sustainable energy technologies and approaches, while leveraging additional funds and involvement from other actors, UNDP can play a critical strategic role in promoting global energy sustainability.

## **IV.2 International Co-operation**

Even though the international community's main response to energy challenges was to focus on increasing energy supply, there was also an interest in supporting efforts that espouse energy efficiency-and-renewable energy. These efforts encompassed multilateral, bilateral, regional, national, grass roots, and private sector efforts.<sup>69</sup> The discussion below provides a brief overview of the main actors in these efforts. More detailed information (e.g., the energy lending/grant criteria, geographical main focus, and ongoing programmes/projects) about the various actors in the field of international energy efficiency and renewable energy can be obtained through UNDP's Energy and Atmosphere Programme (UNDP/BPPS/SEED/EAP).

*The United Nations.* Within the UN, several specialised agencies are involved in various aspects of energy development. Among the specialised agencies, the UNDP is the primary source of funding for energy activities. The primary actor at UNDP is the Energy and Atmosphere Programme, through which the UNDP Energy Account is administered. Part of the UNDP funds available for energy-related activities are channelled through other agencies, including the World Bank, FAO, UNIDO, and UNESCO. Within the UN secretariat, the Department for Development Support and Management Services executes energy projects. The UN regional commissions, most notably the UN Economic Commission for Asia and the Pacific (ESCAP), carry out energy-related activities as well.

*Multilateral Development Banks (MDBs).* The multilateral development banks include the World Bank, the Inter-American Development Bank, the Asian Development Bank, the African Development Bank, the European Bank for Reconstruction and Development, and the Caribbean Development Bank. Together they disburse over US\$ 7 billion annually to the energy sector, representing 20 per cent of all MDB assistance to developing countries. Net disbursements are less

when loan repayment is taken into account.<sup>70</sup> The majority of these funds are in the form of loans for conventional energy exploration, development, refining, conversion, and distribution. Of the MDBs, the World Bank and the Asian Development Bank have been most active in studying opportunities for energy efficiency and renewable energy technologies.

*Bilateral Donor Assistance Programmes.* Many developed countries have established bilateral energy assistance programmes that are in principle targeted to promote energy efficiency measures and renewable energy technologies. Funding for the energy sector represents 7.5 percent of all bilateral development assistance, or approximately US\$ 4 billion in 1993.<sup>71</sup> Much of this assistance is tied to various political, economic, technical, and institutional initiatives and is targeted at conventional energy development, including gas, oil, coal, large-hydro, and even nuclear energy. In many cases, bilateral aid is provided in the form of technical assistance, experimental equipment, and training. A partial list of the bilateral donor assistance agencies active in the energy sector is presented here:

Australia: Australia Aid Organisation (AUSAID)

Belgium: Belgian Administration General of Co-operation for Development (AGCD);

Canada: Canadian International Development Agency (CIDA);

Denmark: Danish International Development Agency (DANIDA);

Finland: Finland International Development Agency (FINNIDA);

France: French Agency for Energy Management (AFME);

Germany: German Agency for Technical Co-operation (GTZ);

Italy: Italian Ministry of Foreign Affairs, Directorate for Development Co-operation (DIPCO).

Japan: Japanese Ministry of Foreign Affairs; Japanese International Co-operation Agency (JICA); Overseas Economic Co-operation Fund (OECF);

The Netherlands: The Netherlands Ministry of Foreign Affairs, Directorate General for Development Co-operation (DGIS);

New Zealand: New Zealand Development Assistance Division (NZ/DAD)

Norway: Norwegian Ministry of Development Co-operation (NORAD);

Sweden: Swedish International Development Agency (SIDA);

United Kingdom: Overseas Development Administration (ODA)

United States: US Agency for International Development (USAID).

*Regional Inter-Governmental Organisations.* In the last ten to fifteen years, several regional institutions have established regional programmes to help promote energy efficiency and renewable energy technologies. These regional programmes include the Latin American Organisation for the Development of Energy (OLADE), the Pacific Forum Secretariat (PFS), and the Southern African Development Co-ordination Conference (SADCC). These regional organisations generally rely primarily on the multilateral and bilateral donors for financial assistance to carry out their energy programmes. They typically have two to three donors who might have considerable influence on their energy agenda.

*Non-Governmental Organisations (NGOs).* A large number of non-governmental organisations have gained an interest in energy efficiency and renewable energy technologies. The best known include the International Institute for Energy Conservation (IIEC), the Stockholm Environment Institute (SEI), the Tata Energy Research Institute (TERI), the Renewable Energy and Environmental Conservation in Developing Countries (REECA), the Biomass Users Network (BUN), and the recently established International Energy Initiative (IEI). A few, like BUN and IEI, are basically South-South oriented.

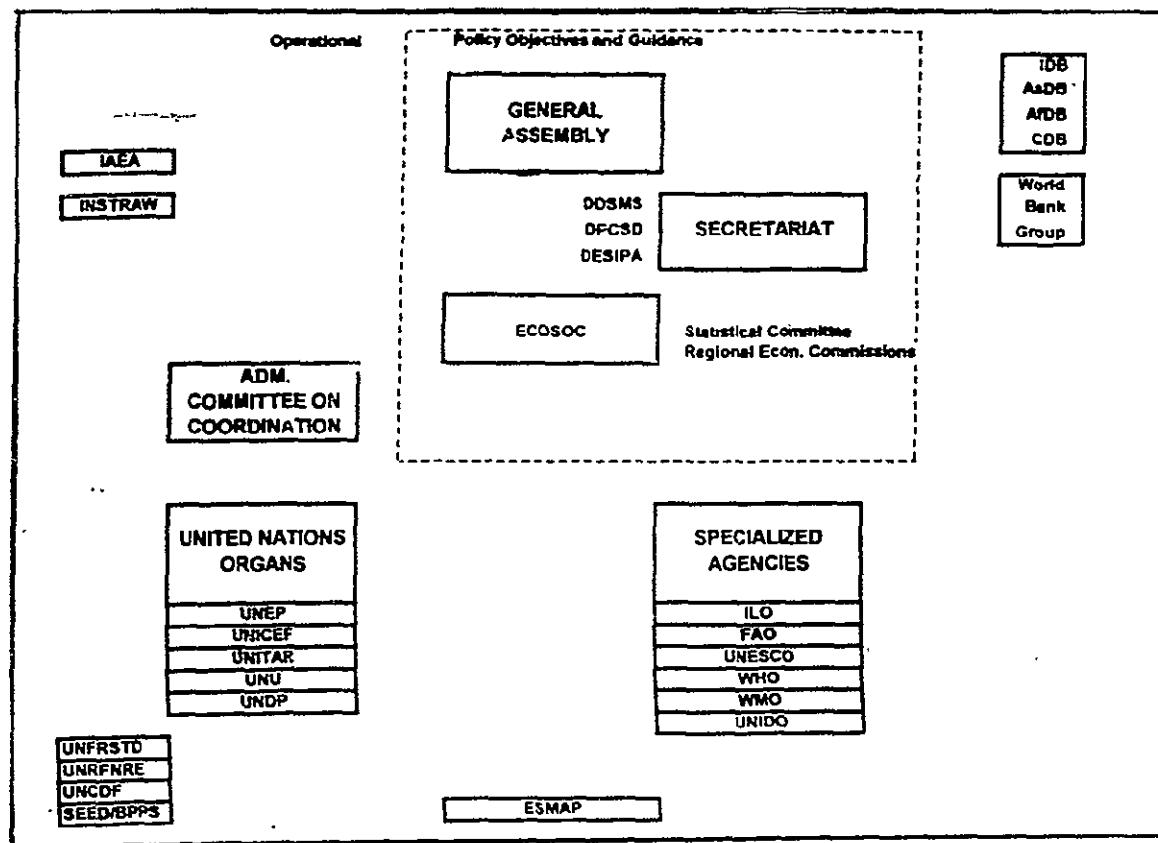
#### *UNDP and the UN System*

At the intergovernmental level, several bodies are involved in formulating normative objectives related to energy. These bodies include the General Assembly and its subsidiary bodies as well as the Conference of the Parties to the Framework Convention on Climate Change and its subsidiary inter-governmental bodies. The UN system should work efficiently to implement the objectives agreed upon in these bodies. To date, operational efforts within the United Nations system have been primarily directed at nuclear, oil, natural gas, coal, and large-scale hydropower. Different functions for addressing energy issues are assigned to various units within the United Nations. Figure 18 presents an overview of the UN system institutions with energy activities.

Although energy is an important item in the debate on sustainable development, the UN system's efforts in this area are relatively weak and diffused. An institutional vacuum exists within the UN system in matters related to energy. Recent environment and development debates -- including within the UN Committee on New and Renewable Sources of Energy and on Energy for Development (UNNRSEED) -- have emphasised the need to strengthen the UN system in this area. Energy efficiency, and renewable energy sources in particular, have not been given priority. The

necessary functions, if they have been assigned to some institution within the UN system at all, are scattered and weakly supported. This approach is not consistent with what is required to maximise energy's potential to support environment and development goals. According to the Committee, the UN system needs to be strengthened, and co-ordination improved, with respect to its ability to help countries move towards a sustainable energy system.

Through UNISE, UNDP can actively work towards greater integration and co-ordination on energy-related issues within the UN and towards more sustainable energy approaches and choices.



*Figure 18. UN System Institutions with Energy Activities*

### *UNDP and the Global Environment Facility*

The Global Environment Facility (GEF) is designated as the interim financial mechanism of the UN Framework Convention on Climate Change and other conventions. The GEF is governed by an Executive Committee and has its own Secretariat. UNDP, UNEP, and the World Bank are implementing agencies within the GEF that are mandated to deliver project assistance. GEF, recently restructured, has a strengthened mandate to link its projects with national sustainable development efforts and to complement, not replace, the implementing agencies' regular development assistance financing. There is thus a strong pressure to ensure complementarity between UNDP and GEF programme objectives.

GEF supports projects and programmes with global environmental benefits. In the area of climate change, GEF will work to expand, facilitate, and aggregate the markets for the needed technologies to reduce greenhouse gas emissions and promote non-carbon alternatives, as well as to improve these technologies' management and utilisation. The emphasis is two-pronged: a) to remove barriers to implementation of climate-friendly, commercially viable technologies, and b) to reduce the cost of prospective technologies that are not yet commercially viable. Toward this end, programmes will be designed to a) remove barriers to energy conservation and energy efficiency, b) promote the adoption of renewable energy by removing barriers and reducing implementation costs, and c) reduce the long-term costs from greenhouse-gas-emitting technologies. The GEF stresses a programme approach and the shared responsibility to address climate change. GEF assistance should complement, or be a component of, larger national initiatives addressing energy issues and climate change. Great importance is placed on national government policy initiatives and financing to ensure that all GEF-supported national programmes are sustainable in the medium term.

The GEF funds the *incremental* costs of a climate-friendly project, that is, the added costs over and above the baseline costs of a conventional project that might otherwise be chosen in the absence of efforts to improve the global environment. Incremental costs may include the capacity-building and institution-strengthening activities needed at the national level to address greenhouse-gas-reduction activities in the productive sectors.

By enhancing their partnership, UNDP and GEF can simultaneously meet their own priorities and advance the goals of national and global sustainable development, building a portfolio of projects "based on country priorities and global benefits." UNDP brings to this partnership its vision and commitment to sustainable development; a system of country offices and projects relevant

to, but outside of, GEF's scope and participation; a well-developed organisational structure with the demonstrated capacity to disburse GEF funds rapidly and effectively; and a commitment to environmental regeneration as one of its priority programme areas.

GEF, in turn, strengthens UNDP's ability to be effective in global environment and energy issues. GEF brings to the partnership means of testing innovative methods of reconciling protection of the global environment and national development goals; experience in mobilising private sector support for environment and development activities; focus and sets of country-approved goals that can help UNDP facilitate resolution of economic and political issues; and prospects for substantial new resources for UNDP, since partial GEF financing can make UNDP projects more attractive to potential donors.<sup>72</sup>

Through UNISE, UNDP can work towards an enhanced partnership with GEF, strengthening the impact not only of its own projects, but those of GEF as well. GEF projects may be designed not only to support the global environment, but to meet such UNDP objectives as job creation and capacity building. UNISE activities and goals are consistent with those of the restructured GEF, which emphasises efficient use of energy and renewable energy sources. GEF's objectives are to reduce market barriers and to introduce new technologies. Thus the UNISE agenda can be met in part by co-operating with GEF. The challenge is to find ways to direct UNDP's resources into the baseline costs and to access GEF financing for the incremental costs of energy projects that are consistent with both UNISE and GEF's operational programmes. In this way, UNDP core resources can be used strategically to leverage additional GEF financing for projects which address energy's relation with, or impact on, the global environment.

#### *UNDP Co-operation with Other International Partners*

UNDP has an important role as facilitator in several new arrangements. One example is UNDP's Memorandum of Understanding with the E-7 Network of Expertise for the Global Environment. The E-7 is an international group consisting of eight leading utilities in G-7 countries. The E-7 members extend their experience, competence, and know-how by providing pro-bono advice to international institutions and to governments in developing and Eastern European countries on global issues related to the electric utility industry and environment and sustainable energy development. This helps leverage UNDP funds, thus contributing to increasing the overall level of environmental advisory services.

A second example is UNDP's co-operation with the World Business Council for Sustainable Development (WBCSD), under which energy, water, and waste disposal projects are jointly designed and implemented in several countries. UNDP also co-operates closely with the International Energy Initiative, E&Co. (an energy investment service) and the Solar Electric Light Fund, Stockholm Environment Institute, Energy 21, and other non-governmental organisations. UNDP will also continue to expand its co-operation with the various international, regional, and national NGOs active in the broad field of energy.

#### *UNDP as Funder of Pre-Feasibility Studies*

UNDP can fund pre-feasibility studies for projects to be funded by the multilateral development banks, bilateral donors, or the private sector. This approach is currently used in the FINESSE programme, with funding from the UNDP Energy Account allocated for market surveys and for preparation of business plans using alternative energy opportunities (Box 7). The multilateral development banks then provide follow-up investment. The preliminary studies are prepared in close collaboration with these banks and take consideration of their lending criteria. Consequently, when the studies are completed, the lending institutions can move quickly to undertake an appraisal for lending purposes.

#### ***Box 7. Large Lenders Provide Loans to Small-Scale Energy Users***

The Financing Energy Services for Small-Scale Energy (FINESSE) project is designed to make the financial resources of multilateral lending institutions available to small-scale energy users who often have no means of accessing credit. Under FINESSE, large multilateral lending institutions provide loans "wholesale" to intermediary organisations in developing countries (e.g., development finance institutions, commercial banks, utilities, private sector firms, non-governmental organisations, etc.), who in turn provide them at market rates at the village level.

FINESSE is a joint UNDP/World Bank, US Department of Energy, and Netherlands project. It operates by: a) bundling renewable energy and energy conservation projects into financing packages large enough to attract international lending agency support; b) incorporating such projects into national energy planning decisions; c) selecting appropriate intermediary institutions; and d) providing technical assistance and training. Through FINESSE, the multilateral institutions are able to provide resources to small-scale energy users without incurring high overhead costs in administering small loans, and end users, who might otherwise lack access to credit, can obtain funds. Examples include:

\* A national energy utility receives funds to purchase and distribute energy-efficient appliances to household, commercial, and industrial users who pay for them through the monthly utility bill.

\* In order to promote local production of alternative energy products and services, a donor provides support in offering local packaging and manufacturing firms loans, loan guarantees, equity and quasi-equity investments, underwriting, standby financing, equipment leasing, credit lines, export financing, or venture capital support.

\* A manufacturer receives donor support to provide franchisees with packaged systems or components that provide high-quality energy services at reasonable costs, which the franchisees in turn offer to consumers. Franchisees receive training on products, marketing, installation, operation, and business start-up requirements. Consumers pay a monthly fee to cover capital and operating costs.

\* A non-governmental organisation receives support to work with village organisations to set up, administer, and manage a system of providing renewable energy services in rural areas. These services may be in the form of mini-utilities or individual systems for residential, agricultural, or small-scale industry needs.

*The Joint UNDP/World Bank Energy Sector Management Assistance Programme  
(ESMAP)*

Since its creation in the mid-1980s, ESMAP (whose predecessor was the UNDP Energy Sector Assistance Programme) has been operated by the World Bank and partially supported by other donors. The objectives of ESMAP are to conduct sector assessments and develop overall energy strategies for developing countries requesting such assistance; provide technical management, policy and institutional assistance in energy; carry out energy related pre-investment studies in areas not traditionally addressed by World Bank lending (i.e., energy efficiency and renewables); and stimulate other development institutions to work toward these efforts as well. The studies conducted are primarily in the natural gas and petroleum sectors, and in the household sector. ESMAP has, at various times, helped to lay the groundwork for subsequent World Bank loans. To some extent, ESMAP's work already supports sustainable energy initiatives. UNDP should stimulate ESMAP increasingly to work on sustainable energy approaches outlined in UNISE.

#### **IV.3 UNDP's Own Offices**

If UNDP is going to help catalyse the transition to a more sustainable global approach to energy, both headquarters and field staff must have stronger technical capacity in the area of sustainable energy. This internal capacity-building effort must involve staff from headquarters, the regional bureaux, the field offices, and the countries (governments, NGOs, and the private sector) and must utilise and build on UNDP's rich experience.

One of UNDP's often cited comparative advantages is the network of country offices in every region of the world. As the discussion has shown, the ability to promote sustainable energy will hinge upon bringing together the interests of energy consumers (especially the poor), energy providers, technology providers, private sector financing, and government institutions. UNDP is

uniquely placed to promote these networking activities and to provide the overarching programme vision to link energy sector activities with other sustainable human development efforts. Within each country, UNDP offices should be encouraged to forge linkages between groups and to leverage new financial flows from capital and technology providers through catalytic programme support for the development of business plans, national energy planning agencies, demand side management programmes, and innovative financing schemes to promote commercialisation and dissemination of renewable energy technologies

Finally, UNDP, like the UN system as a whole, must also bring energy efficiency to its own facilities. As an initial step, UNDP plans to contract energy service companies to audit its buildings and to adopt a system wide Green Office Initiative involving the promotion of energy efficiency.

## **V. CONCLUSION: ENERGY AS AN INSTRUMENT FOR UNDP PRIORITIES**

UNDP has set, as one of its main goals, to help the entire UN system to become a powerful force for sustainable human development -- i.e., development that is people-centred, that both generates economic growth and distributes the fruits of growth equitably, and that empowers people to participate in the decisions that shape their lives. Specifically, UNDP has determined that it will focus on four key aspects of sustainable human development -- eradicating poverty, providing people with income-earning opportunities, increasing women's role in development, and protecting and regenerating the environment. Energy can either serve as a barrier to achieving these objectives or it can become an instrument for attaining them.

As countries develop, their needs for energy services expand and develop. How those needs are met has significant implications for the environment and the continued capacity of countries to grow. If current patterns of energy production, distribution, and consumption continue and spread to other countries, development and growth in at least some of those countries could slow dramatically. What is needed are new, more efficient systems for producing, distributing, and consuming energy as well as increased reliance on environmentally sound energy systems that contribute to economic growth and expand people's opportunities.

### **V.1 Energy and Poverty Eradication**

For the poor, the first priority is the satisfaction of such basic human needs as access to jobs, food, health services, education, housing, running water, sanitation, etc. Energy plays an important role in providing for these needs.

Low energy consumption is not a cause of poverty, and energy itself is not a basic human need. But the lack of available energy has been shown to correlate closely with many poverty indicators. Addressing the problems of poverty requires addressing its many dimensions — poor education, bad health care, inadequate sanitation, etc. Addressing these issues involves increasing the level of energy *services*.

Conventional energy strategies for the most part have failed to help meet the basic human needs of the poor majority. Yet numerous possibilities exist for meeting basic needs at much lower energy consumption levels than has traditionally been the case. By using the most efficient technologies available today, and focusing increasingly on renewable sources of energy, the level of

energy services can be increased considerably. Those increased services are essential for meeting basic human needs and alleviating poverty.

### **V.2 Creating Jobs**

Throughout the world, hundreds of millions of people are unemployed or underemployed. Creating income-earning opportunities for these people is an essential pre-requisite for long-term sustainable development and a major focus of UNDP's work.

Renewable energy, in particular, offers significant possibilities for job creation. A program to produce ethanol from sugar cane in Brazil, for example, helped create about 700,000 jobs in rural areas. Such jobs help to reduce rural-to-urban migration, and the increased tax base in rural areas helps to create new, and to improve existing, infrastructure. Similarly, biomass production for fuel -- either on plantations or by small-scale farmers -- has the potential for creating a significant number of jobs in some countries.

### **V. 3 Increasing Women's Role in Development**

Throughout the world, the poor pay a much higher price -- in terms of both time and labour -- for the high costs of energy and/or its lack of availability. Women, often among the poorest people in society, are particularly affected, often spending four to six hours per day and walking up to ten kilometres to gather 35 kg of firewood. Women are also particularly affected by the health hazards associated with inhaling smoke from inefficient stoves, which may convert only 10-15 percent of the energy contained in the fuelwood into useful energy for cooking. Girl children are withdrawn from schools over boys when family decisions concerning children and fuel gathering are taken. Female-headed households, in which women must both perform these traditional functions and provide fully for their families, are particularly vulnerable.

UNDP's commitment to advancing the opportunities available to women requires a serious commitment to addressing the energy issues that can undermine women's opportunities and health.

### **V.4 Protecting the Environment**

Conventional energy strategies impact negatively on the environment by contributing to land degradation, acidification, and global warming. While the theoretically ideal solution might be not to produce or consume energy, this is not a realistic alternative. Developing countries must increase

their level of energy services if they are to achieve acceptable levels of human development. Thus the issue must be to provide needed levels of energy services without unacceptable negative environmental consequences.

\* \* \*

The extensive experience of UNDP and other agencies has provided useful lessons about how to balance the goals of providing increased energy services without increasing the environmental and human costs. UNISE attempts to draw on that experience and to build widespread capacity for pursuing environmentally sound energy and development strategies.

Energy is not a goal in itself. It is the means to achieving many objectives inherent in the larger goal of sustainable development, including the priorities defined by UNDP for its own work. Moreover, those priorities cannot be achieved without a higher level of energy services. Rather than pursue the conventional assumption that increased energy consumption is required if energy services are either to increase or be more widely available, UNDP should pursue a conscious and concerted approach of expanding energy services without increasing consumption.

UNISE provides a comprehensive approach for UNDP's work in this area. It also gives UNDP the opportunity to help move countries and other institutions towards more sustainable energy strategies and ultimately towards more sustainable.

*Appendix*

***ENERGY AND UNDP – LESSONS LEARNED***

During the late 1970s and the 1980s, the UN General Assembly passed resolutions reaffirming the right of developing countries to exploit their indigenous energy resources. These countries had rapidly increasing demand for energy, and it was clear that severe future energy supply shortages could occur unless new energy sources were developed.

There was a surge in energy investment, primarily in fossil fuel exploration and development. The longer-term importance of new and renewable sources of energy was also stressed, particularly at the UN Conference on New and Renewable Sources of Energy in Nairobi in August 1981. The World Bank and the regional development banks initiated large energy exploration and development programmes, often in conjunction with private sector initiatives.

UNDP began to receive requests from developing countries, channelled through UN system agencies, for technical assistance in energy planning, energy efficiency and conservation, energy supply enhancement, and development of new and renewable sources of energy. Since it did not have an overall energy sector policy, UNDP responded to these requests by providing funding based on country requests and needs.

Over the last two decades, UNDP has committed over US\$ 400 million to energy sector activities. In the period 1974-94, UNDP provided funds for over 900 projects in Africa (211), Asia/Pacific (292), Latin America (202), Arab States (81), and Eastern Europe (59) (Table 1). These projects were in the areas of energy planning (373), energy efficiency and conservation (49), conventional energy (242), electric power (103), nuclear energy (68), and new and renewable energy (81) (Table 2). The cost-sharing contributions amounted to US\$ 84.2 million.

These data show that UNDP funding of US\$25 million on new and renewable sources of energy generated an additional 35 percent in cost-sharing funds (US\$9 million), and UNDP funding of US\$19 million for energy conservation generated an additional 53 percent in cost-sharing funds (US\$10 million). However, the bulk of UNDP energy funding during this period went to conventional energy, that is, oil, gas, and coal (US\$141 million), which only generated an additional 27 percent in cost-sharing funds (US\$38 million). Clearly, energy planning, conservation, and electric power, along with new and renewable sources of energy, were able to attract much higher levels of both donor government and host government funding.

*Table 1: UNDP Energy Sector Projects, 1974-1994, by Region*

Region	Projects (number)	UNDP contribution (US\$ million)	Cost sharing (US\$ million)	Total contribution (US\$ million)	Share of Total (%)
Asia & Pacific	292	208	21	229	46
Africa	211	71	5	76	15
Arab States	81	29	2	31	6
Europe	59	20	1	21	4
Latin America	202	63	33	95	19
Interregional & Global	71	21	28	50	10
<b>Total</b>	<b>916</b>	<b>412</b>	<b>90</b>	<b>502</b>	<b>100</b>

*Note:* UNDP/GEF projects and projects smaller than US\$ 10,000 are excluded.

*Source:* J. Gururaja, *Evaluation of UNDP Assistance to Energy Sector*, UNDP (August 1995).

*Table 2: UNDP Energy Sector Projects, 1974-1994, by Sub-Sector*

Sub-sector	Projects (number)	UNDP contribution (US\$ million)	Cost sharing (US\$ million)	Total contribution (US\$ million)	Share of Total (%)
Energy Planning	373	139	31	169	34
Energy Efficiency	49	19	10	29	6
Oil & Natural gas	197	120	38	157	31
Electric Power	103	65	1	65	13
Coal	45	21	0	21	4
Renewable Energy	81	25	9	34	7
Nuclear Energy	68	24	1	25	5
<b>Total</b>	<b>916</b>	<b>412</b>	<b>90</b>	<b>502</b>	<b>100</b>

*Note:* UNDP/GEF projects and projects smaller than US\$ 10,000 are excluded.

*Source:* J. Gururaja, *Evaluation of UNDP Assistance to Energy Sector*, UNDP (August 1995).

UNDP funding of energy sector projects during the two-decade period consisted of individual country projects, regional projects, inter regional projects, and global projects. UNDP involved a wide range of UN system agencies in both project design and implementation. The list below indicates the various agencies/programmes involved in different kinds of projects:

- *National energy sector reviews*: ESMAP (The joint UNDP/World Bank Energy Sector Management Assistance Programme, which was preceded by the Energy Sector Assistance Programme);
- *Energy policy, management, economics, and legislation*: ESMAP, UNDDSMS, ECA, ECE, ECLAC, ESCAP, ESCWA, UNIDO, UNESCO, UNCTAD;
- *Energy information systems*: UNDIESA, UNDDSMS, ECE, ESCAP;
- *Energy efficiency/conservation (power sector, industry, transport, residential/commercial, urban, agriculture)*: UNDDSMS, UNIDO, ECE, ECLAC, ESCAP, ESCWA, ESMAP, IAEA, UNESCO, FAO;
- *Petroleum, gas, coal*: UNDDSMS, UNIDO, ECE, ESCAP, ESCWA;
- *Hydropower (large)*: UNDDSMS, UNIDO, ECE, ESCAP;
- *New and renewable energy sources (solar, wind, biomass, biogas, geothermal, small/minи hydro)*: ESMAP, UNDDSMS, FAO, ECA, ECE, ECLAC, ESCAP, UNIDO, UNESCO; and
- *Nuclear energy safety issues*: IAEA.

Recently, UNDP worked less through other UN system agencies, relying instead on national execution of projects in order to support capacity building. This has led to some problems regarding the quality of development assistance delivered in those countries with weak national capacities or institutions. In other cases, it has provided excellent opportunities for the transfer of successful experiences within countries and between national institutions and centres of excellence.

UNDP's funding of energy sector activities was welcomed by recipient developing countries. It helped energy-endowed developing countries develop their resources and train national staff in cost-effective and environmentally cleaner methods of producing, transporting, and utilising energy resources. Recipient countries were able to explore the potential of using new and renewable energy resources; where possible, these resources were tapped. All recipient countries received assistance in

national energy planning and policy formulation in order to move towards more sustainable energy use over the longer-term. In many countries, UNDP assistance resulted in energy and cost savings, as well as environmental benefits from lower emissions.

Despite its successes, UNDP energy assistance was fragmented, perhaps reflecting the constantly shifting international consensus about what was needed (renewables in the 1970s and early 1980s; conservation and efficiency in the mid-1980s; and concern about the environment in the late 1980s and early 1990s). As a result, UNDP assistance has not, according to a recent evaluation, “produced any recognisable thrust” or “been of help in shaping national and global policies.” The same report argues that the current emphasis on sustainable development and UNDP’s extensive experience in the energy sector create a valuable opportunity. What is needed is a “new action agenda linked to concrete, measurable goals.”<sup>73</sup>

During the evaluated period, UNDP funding of energy activities occurred primarily through allocations by programme countries within their respective Indicative Planning Figures (IPF). In addition, energy-related activities were funded through trust funds such as the UNDP Energy Account and the Global Environment Facility (GEF). The UNDP Energy Account, established by the UNDP Governing Council in 1980, focused on activities aimed at utilising renewable sources of energy to meet the basic energy needs of rural communities and on demand-side management in the residential, commercial, and industrial sectors. In addition, the Energy Account served, albeit to a lesser extent, as the channel for activities under ESMAP.

Since 1992, GEF has funded energy projects related to the climate issue. During the Pilot Phase (1992-94), GEF funded 24 climate-change projects through UNDP for a total of US\$ 97.5 million. These projects dealt with developing strategic information for future decision making (12 projects), reducing emissions through energy efficiency or carbon offsets (6 projects), and developing renewable sources of energy (6 projects). In 1995, GEF funded 15 climate change projects through UNDP for a total of US\$12.8 million, all of which were essentially “enabling activities” to help countries prepare their communications with the Conference of Parties to the Framework Convention on Climate Change.

Because of the decline in UNDP’s regular programme funds and the increasing GEF portfolio on climate change, which covers some energy projects, there was a noticeable tendency within UNDP to give lower priority to funding energy projects under the regular IPF programme. However, this was counter to the spirit and intention of GEF, which was designed to pay only the

"incremental costs of projects to protect the global environment." As discussed in chapter IV, projects that can attract GEF funding generally are consistent with the UNISE strategy. The reconstructed GEF and UNDP -- through UNISE -- should form a strong partnership to mutually enhance their potential contributions to global sustainable development.

#### **Lessons Learned: Building on Experience**

UNDP and other UN agencies have considerable experience in how to pursue development activities and how not to do it. That body of experience should inform current thinking and approaches. The UNDP energy strategy should draw on the data, insights, and lessons learned by development agencies -- in energy as well as other sectors:

*1. Initial feasibility studies should have clearly understood plans for follow-up funding.*

In 1980, the United Nations initiated a small-hydropower evaluation program that sent two- to three-person missions for two to three weeks to developing countries to evaluate their small-hydropower potential. Soon after its inception, this programme became very popular among developing countries and was successful in attracting additional funding from several donors under trust-fund arrangements. Although the United Nations never made such a commitment, the countries got the impression when the missions were first proposed that the UN would subsequently be able to attract donors to put together a financial package for development of at least some of the sites.

After the first fifteen countries were investigated, it became clear that the UN's continuous efforts were unsuccessful in attracting donor funding. However, the programme was allowed to continue to cover more countries (approximately forty altogether). Based on this experience, it is clear that when feasibility studies are conducted, the prospects for follow-up funding should be explored with potential donors, lenders, and the private sector from the outset. Feasibility studies should at least have prospects for funding to implement the studies' recommendations.

*2. Small-scale energy consumers in the developing world who stand to benefit from small-scale renewable energy systems need better access to affordable financing.* A number of barriers at the multilateral, bilateral, national government, and village level serve to distort the market away from renewable energy technologies.

*Multilateral lenders* tend to prefer large-scale power project development in urban areas. The World Bank, for example, is the single most important source of external capital for energy activities in the developing world, with Bank lending for this sector amounting to approximately US\$ 3 billion per year. Most important multilateral lending agencies have poor track records on financing small-scale power projects (not even on a wide-scale basis to achieve economies of scale) and are only recently reconsidering sector lending to promote small scale energy systems development.

Yet small-scale lending for renewable energy is viable when the proper institutional framework exists to administer such a programme. The joint UNDP/World Bank, US Department of Energy, and the Netherlands project entitled FINESSE (Financing Energy Services for Small-Scale Energy Users) is an example. Under FINESSE, large multilateral lenders provide loans "wholesale" to an intermediate, in-country institution for "retail" lending at the village level. This approach prevents the large multilateral institutions from having to incur high overhead costs to administer small-scale loans, while nevertheless putting them in the small-scale lending business.

*Multilateral donors*, on the other hand, have financed renewable energy systems, but these projects have been implemented on a grant basis with no provision for system maintenance. Lack of cost recovery and misuse (often due to improper sizing) have caused some systems to fail.

Donors must build cost-recovery components into renewable energy projects - even those funded on a grant basis -- in order to provide a pool of funds for maintenance and component replacement over the long run. The cost recovery component has been shown to increase the sense of responsibility for and involvement with installed systems of any type on the part of local villagers.

*National governments* also fail to promote renewable energy systems. They engage in technology price distortions, particularly by subsidising fossil fuels. With such subsidies, diesel generators can often easily out-compete renewable energy systems from a strictly financial point of view, resulting in increased dependence on fossil fuel imports in the case of non-petroleum-producing countries, and decreased fossil fuel export performance on the part of producer nations. In both cases, adverse environmental effects from the burning of fossil fuels are maximised instead of minimised.

Lack of life-cycle costing among in-country government agencies is another major obstacle. In-country agencies concerned with rural power, for example, most often compare apples to oranges (capital- versus operations-intensive energy technologies) in their planning exercises. Since the major cost advantage of renewable energy systems is their minimal maintenance and total lack of fuel

requirements, life-cycle costing is essential -- combined with undistorted conventional fuel prices -- to put these systems on a more equal economic footing with diesel generators, for example.

National governments need to re-examine their financing of energy systems, particularly for rural power. They must assess renewable energy options and apply life-cycle costing to provide a level playing field for renewable energy technology, and they must reduce their fuel subsidies.

Barriers to introducing and financing renewable energy systems also exist at the *village* level. Too often, small-scale borrowers are perceived as having no collateral, when in fact the energy system they are borrowing to pay for could be regarded as collateral. Similarly, household photovoltaic electrification may not occur simply because there is no institutional mechanism of loan recovery. One way of dealing with this is to organise villagers into groups that together are responsible for ensuring that all members of the group repay all loans. Another possibility is to on-lend to intermediary private voluntary organisations, which are sometimes more likely to receive loan repayments than commercial business operations.

***3. Donors, lenders, national governments, and village-level users all need more and better information about the potential for meeting the basic energy needs of rural communities through renewable energy.*** Such options as photovoltaics are seen as expensive and high risk.

*Donors and lenders* often do not think of renewable energy as an option. They regard it as high-risk despite its successful track record since the mid-1980s, and they mistakenly believe it is maintenance free. Donors and lenders must be educated about the true positive and negative factors in renewable energy technology. The system must be properly sized based on available supply and demand information. Recipients must be educated about the purposes and goals of the particular technology to be used.

*National governments*, too, are often unaware of the potential of renewable energy technology to meet basic energy needs, with the result that these technologies are left out of the energy planning process. Solutions to this problem include learning from the experiences of neighbouring countries already utilising such technology through seminars and other forms of information dissemination organised by donors and lenders. Governments could set up "consumer energy centres" with responsibility for comparing various renewable energy systems/technologies, establishing distribution networks for the equipment, and training project designers, retailers, installers, and maintenance personnel.

At the *village* level, potential users of electricity are often not aware of the alternatives available. Therefore, before renewable energy technologies are introduced, care should be taken to obtain the interest and participation of users by explaining the purpose of the installation, its limitations, and its advantages and disadvantages relative to other options, and by determining their exact requirements. This dialogue should continue during the implementation/construction stage. In addition, a selected number of villagers should receive training in operation and maintenance.

*4. In energy, as in other areas of development assistance, the private sector and the civil society as a whole must be active partners.* UNDP's Public-Private Partnerships Programme helps to promote the involvement of the private sector and the larger civil society in energy, waste management, and water and sanitation projects in urban and peri-urban areas. The programme is based on the premise that many urban-related problems in developing countries are potentially viable business opportunities that deliver environmentally sound solutions within a socially conscious approach.

Private investors account for 95 percent of energy investment in developing countries. It is essential, therefore, that these investors become partners in sustainable energy development by focusing on demonstration projects and creating an institutional environment that will lead the private sector to choose efficient and environmentally sound technologies.

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